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ORGANIZATION AND USE OF A SOFTWARE/HARDWARE AVIONICS RESEARCH PROGRAM (SHARP)

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FOREWORD

The Avionics Research Branch of NASA Ames Research Center is conducting and sponsoring analysis, simulations and flight tests to assess the microwave landing system (MLS) requirements for STOL aircraft operations and evaluate prototype MLS equipment for STOL aircraft. Aircraft must transition to and from the MLS in the terminal area, and the performance of each individual system affects that of the others. The merits of each of the alternate MLS implementations must be determined and compared to enable making a clear decision on further developmental efforts required.

As a part of the STOL aircraft research program at Ames, the STOLAND ground cockpit simulator complex was developed. A unique feature of this facility is that it duplicates the avionics portion of the airborne system, including all interfaces. The purpose of this effort was to develop a software program to duplicate the automatic portion of the STOLAND simulator system, on a general-purpose computer system (i.e., IBM 360). This enables a wider group of Ames Research Center personnel to conduct meaningful research studies in STOL aircraft systems.

This report presents the organization and use of the software/hardware avionics research program (SHARP) developed for the above effort. The program's uses are: (1) to conduct comparative evaluation studies of current and proposed airborne and ground system concepts via single run or Monte Carlo simulation techniques, and (2) to provide a software tool for efficient algorithm evaluation and development for the STOLAND avionics computer.

The development of this program was supported under NASA Contract No. NAS2-8344, by Ames Research Center, Moffett Field, California. Project monitor was C.N. Burrous. The project manager and project engineer for this phase of the study at Systems Control, Inc. (Vt) were J.S. Karmarkar and M.N. Kareemi, respectively.

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I. INTRODUCTION

The microwave landing system (MLS) is a high priority national program to replace the present Instrument Landing System (ILS) at all U.S. airports. The program is interagency in scope and includes the Department of Defense, Department of Transportation, and NASA. Ames Research Center's role in this program involves: (a) the development of various MLS operational requirements via aircraft simulations; (b) evaluation of a prototype MLS for short take off and landing (STOL) aircraft operations; and (c) development of various low cost MLS airborne receiver subassemblies.

To conduct the research entailed by item (a) above, it was recognized that a software/hardware avionics research digital computer program (SHARP), operable on a general-purpose computer (IBM 360/67), was needed. Although a realistic piloted/automatic cockpit simulator (e.g., STOLAND) of a STOL aircraft was operating at Ames, the principal reasons dictating need of a general-purpose computer program were requirements for: (a) greater availability, (b) ease of programming/modification, and (c) extensive debugging/ printout capabilities. This report presents the details of the program developed for this purpose; the C-8 aircraft model, equations of motion, environmental disturbances, and the interface with the avionics software used in the program were developed under a separate contract. Program SHARP, operating in the interactive or batch mode, can be used by researchers for two purposes, namely: (a) comparative analysis of various navigation, guidance, and control policies, and (b) efficient software development of novel navigation, guidance and control concepts. The program for conducting these two general classes of research projects is presented in this report.

Chapter II of this report presents the capabilities of the program SHARP in terms of avionics software development procedures and Monte Carlo simulation studies. Prospective users of this pro-

gram can obtain an overview of the scope of this research tool from this chapter.

For researchers intending to use this program, Chapters III and IV cover the implementation and operating details of the program. Additional program documentation on aircraft dependent parameters and the aircraft/avionics interface are provided in Appendices A and B, respectively.

Chapter V presents the validation procedures used to check the program and the corresponding results. This chapter also discusses the main differences between the IBM 360 SHARP program and the STOLAND cockpit simulator system. It is noted that the present version of the SHARP program completely simulates the fully automatic mode of the STOLAND C-8 simulation.

II. CAPABILITIES OF THE SHARP PROGRAM

Essentially, program SHARP ducplicates, in FORTRAN, the automatic portion of the STOLAND simulator complex, for the C-8 aircraft. Software details and usage procedures are documented in the following chapters. This chapter is devoted to elaborating on the manner in which this program can be used to conduct avionics research.

The SHARP software executive program has been set up to cycle automatically through a prespecified set of runs in a Monte Carlo mode and calculate statistics for a prespecified set of variables of interest. Consequently, the package can be used to conduct a number of comparative studies. Some of these are:

(a) Comparative analysis of navigation systems - ILS (CAT I, II, III), MLS, VOR/DME, Inertial.

(b) Control law performance - 3D, 4D, gust alleviation, direct lift control (DLC), flare optimization.

(c) Mode transition studies - MLS/RNAV transition.

This automated simulation capability thus provides an invaluable complement to the STOLAND computer complex.

Areas of software development which correspond to the comparative study topics mentioned above include:

(a) Navigation concept development - dead reckoning, air data, hybrid navigation (e.g., inertial blended with VOR/DME), complementary filters, Kalman filters, etc.

(b) Control law development - autothrottle/autopilot design, flare optimization, etc.

(c) Guidance concept development - 2D, 3D, 4D guidance, etc.

(d) Software/hardware trade off analysis - core space usage, computation time, hardware specification, etc.

The following sections present an outline of the Monte Carlo analysis and software development procedures.

2.1 MONTE CARLO ANALYSIS

The Monte Carlo analysis procedure essentially consists of implementing in software the aircraft/avionics/ground system configuration being studied and making a sufficiently large number of runs to generate significant statistics on a prespecified set of variables.

For example, to obtain a quantitative measure of lateral navigation performance, representative trajectories are defined and recursive formulae are used to compute the mean and variance of the error between the nominal and the actual for a prespecified set of points along the trajectory. Use of recursive formulae significantly reduces the storage requirements for a large number of Monte Carlo runs. The recursive formulae for the mean (η_k) and the variance (σ_k^2) at the kth step are given by:

$$\eta_k = \frac{1}{k}\{(k-1)\eta_{k-1} + s_k\} \quad ; \quad \eta_o = 0 \qquad k=1,2,3,\ldots$$

$$\sigma_k^2 = \frac{1}{k-1}\{(k-2)\sigma_{k-1}^2 + (\eta_k - s_k)^2\} \; ; \; \sigma_1^2=0 \qquad k=2,3,4,\ldots$$

where

$$s_k = (X_k^a - X_k^n)$$

X_k^a = actual state vector

X_k^n = nominal state vector

Monte Carlo simulation results for a typical trajectory are presented in Chapter IV, Section 4.5.

2.2 AVIONICS SOFTWARE DEVELOPMENT

The IBM 360/67 time-shared system (TSS) remote terminal edit/debug features allow systematic development of well documented programs. The TSS facility allows one to step through programs for debugging (e.g., checking for overflows), thus speeding up implementation of these programs on typical airborne computers such as the Sperry avionics computer (1819A). In addition, useful estimates are obtained for core space usage and computation time.

A simple example illustrates the procedural steps for program development. The program NEWFL was first written in floating point notation (FORTRAN), together with scaling (SCALN) and unscaling (USCAL) programs. These programs ensure that the fixed point (integer arithmetic) main avionics program and the floating point portions of the software being developed are compatible. In other words, the program USCAL converts scaled quantities from the avionics program to unscaled floating point numbers and SCALN performs the inverse of this process. These programs are imbedded in the STOL avionics executive (STLEXC) as shown in Fig. 2.1. Details on scale factors are documented in Appendix B, and the appropriate Sperry documents.

After the program NEWFL has been debugged (e.g., Syntax errors and computational algorithm errors), it is converted to a fixed point integer version NEWFI and the scaling/unscaling routines are removed. Debugging at this stage consists of checking for overflows and underflows. The TSS terminal facilities are very valuable at this stage for stepping through the program. Additional information that can be generated at this point is core space requirements and computation time.

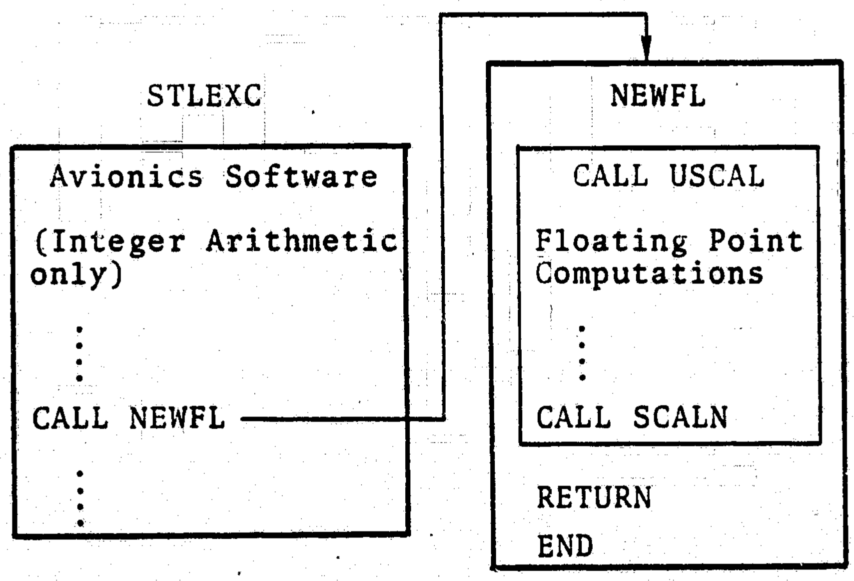

FIGURE 2.1: FLOATING POINT VERSION OF NEW PROGRAMS (NEWFL)

The next step in program development is to convert the integer format program NEWFI to the assembly language (1819A) version and to debug it on the STOLAND simulator. The time required to accomplish this step is greatly reduced because of the earlier steps. Moreover, the user can keep track of the state of program development, since a major portion of it is being done in FORTRAN.

For purposes of illustration, a typical STOLAND assembly language routine LATINT is shown in Fig. 2.2. The corresponding FORTRAN fixed point program is given in Fig. 2.3. It can be seen that the FORTRAN version of the program allows researchers to maintain adequate documentation for the corresponding assembly language program.

FIGURE 2.2: TYPICAL STOLAND ASSEMBLY LANGUAGE PROGRAM

```
$****************************************************************
$
$ THIS ROUTINE LOADS THE LATERAL INTEGRATOR
$
1 2340   00 0000   LATINT  0'0          LATERAL INTEGRATOR LOAD
1 2341   44 1161           STRAL'DZG5
1 2342   12 1255           ENTAL'ZG5
1 2343   24 1770           MULAL'LATD2
1 2344   26 4230           DIVA'D1000
1 2345   14 2003           ADDAL'PHICOM
1 2346   44 2003           STRAL'PHICOM
1 2347   65 2351           JPALP'LOK+2
1 2350   50 6100           CPAL
1 2351   71 4367           ADDALK'-1800D
1 2352   65 2355           JPALP'CLRLIN
1 2353   12 1631           ENTAL'HORNAV
1 2354   63 2356           JPALNZ'LOK+2
1 2355   40 1161   CLRLIN  STRZ'DZG5
1 2356   55 2340           IJP'LATINT
$****************************************************************
```

FIGURE 2.3: FORTRAN (FIXED POINT) EQUIVALENT OF LATINT

```
C    *
      SUBROUTINE LATINT
C    ***********************************************************************
C         *
C         *      SUBROUTINE TO INITIALIZE LATERAL INTEGRATOR FOR ANY LATERAL MODE
C         *  THAT USES INTEGRAL. IT IS CALLED BY LOCT, WHICH IN TURN IS
C         *  CALLED BY RMLS. IT IS STORED AT  12340
C         *
C         *
C     BLOCK50
C    ***********************************************************************
C
      COMMON /STL/ IA(1400)
C
      EQUIVALENCE (IAL,IA(6)),(IDZG5,IA(534)),(ILATD2,IA(193)),(IHRNAV,
     1 IA(152)),(IPHCOM,IA(226)),(IZG5,IA(651))
C
C
C    *
C    *
C
      IDZG5 = IAL
C
C     ROLL COMMAND
C
      IPHCOM =  IPHCOM   + (IZG5*ILATD2)/1000
C
C     CHECK IF ROLL COMMAND.GT. 5 DEGREES.
C
      IAL =  IABS(IPHCOM) - 1800
      IF( (IAL.GT.0).OR.(IHRNAV.EQ.0) ) IDZG5 = 0
  100 RETURN
      END
```

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To summarize, the program development steps are:

(1) Develop FORTRAN floating point program for the proposed algorithm and debug it.

(2) Convert program to fixed point version with proper scale factors and debug it.

(3) Convert program to Sperry 1819A assembly language and debug it on the STOLAND simulator.

Although this sequence of steps appears to be rather tedious, the overall program development time is significantly reduced due to minimal debugging time for step 3. Moreover, the FORTRAN versions of the program serve as effective documentation records that are easily understood by all interested personnel.

III. IMPLEMENTATION OF SHARP

This chapter provides implementation details of SHARP. These details are essential for maintaining, modifying, and using the avionics research package.

First, an overview of the STOLAND real time simulator is given (Section 3.1). This is followed by a description of the TSS version of the simulator (Section 3.2). The aircraft dependent routines and parameters have been identified (Appendix A); these will aid in changing the aerodynamic characteristics of the aircraft in the simulation. Section 3.3 details the avionics implementation of SHARP.

3.1 STOLAND REAL TIME SIMULATION

The 1819/8400 STOLAND simulator system was developed to facilitate simulator research of V/STOL terminal area navigation, guidance, and control concepts. The resultant research tool is an integrated digital system using ARINC specified airborne hardware. The simulated facility (Fig. 3.1) uses the EAI 8400 digital computer to simulate the C-8A aircraft, ground-based navigation aids (such as VOR/DME and MLS), and winds. An avionics equipment rack containing ARINC specified airborne hardware and an airborne hardware simulator for transforming the NAVAID information generated on the EAI 8400 to the form received by the airborne receivers is included. The simulation cockpit (Fig. 3.2) contains standard airborne instrumentation together with advanced display and mode select systems. In addition, an EAI 8800 analog and logic computer, simulating the control surface servos and interlock logic, and a data conversion rack to electrically interface all these subsystems are included in the system.

SIMULATION FACILITY

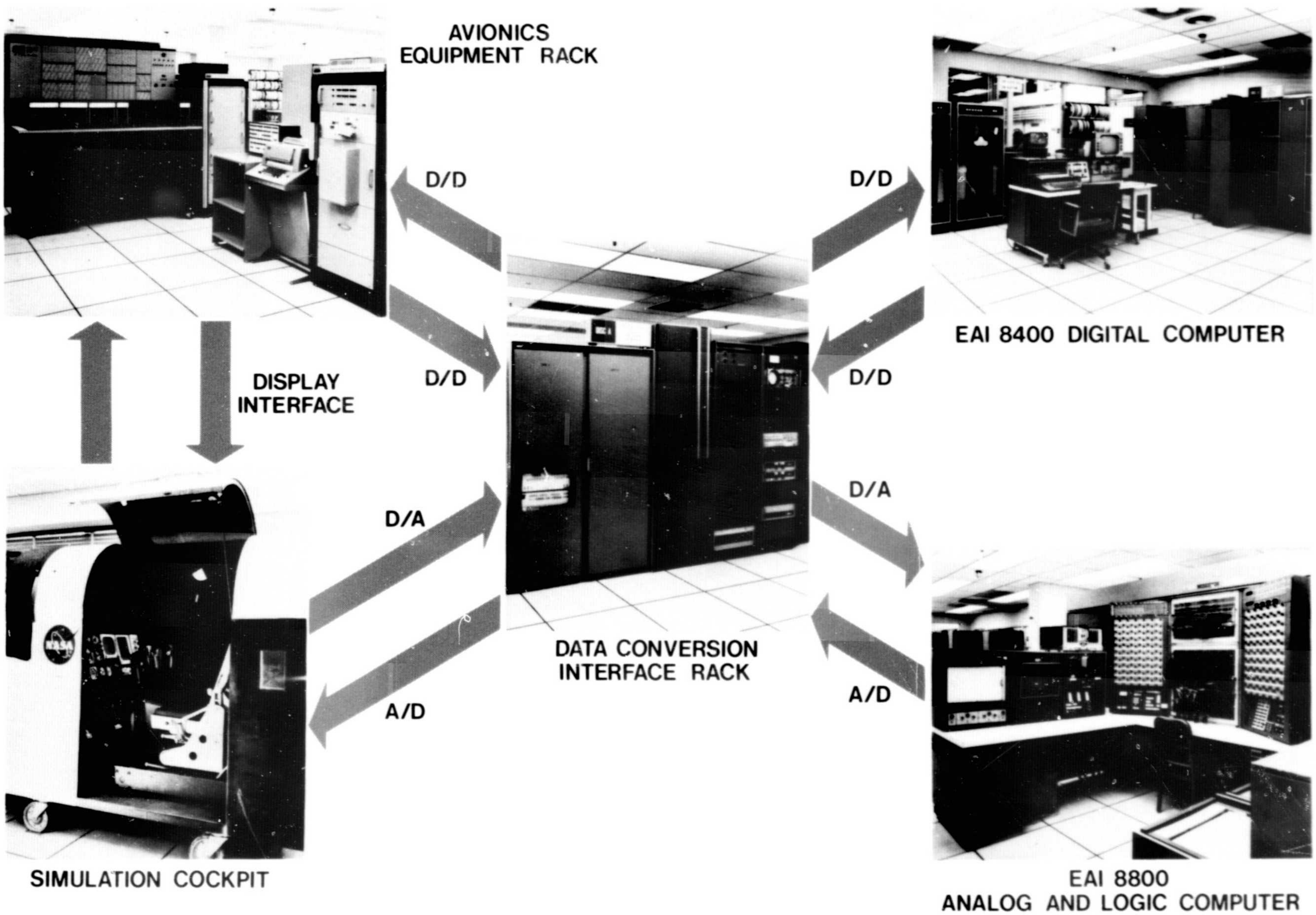


FIGURE 3.1: SIMULATION FACILITY

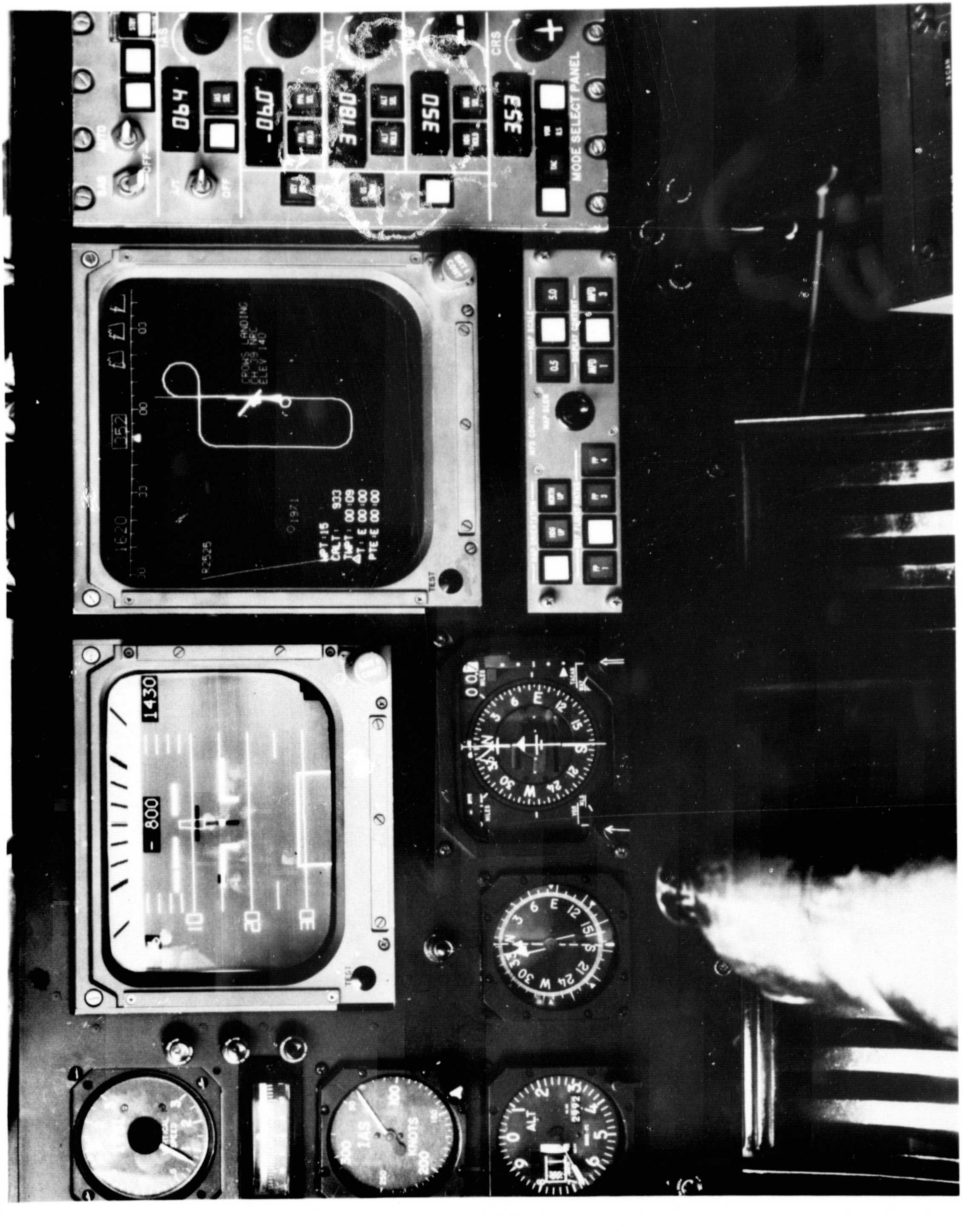


FIGURE 3.2: SIMULATOR COCKPIT

A block diagram of the STOLAND airborne hardware which is used in the STOLAND simulator system is shown in Fig. 3.3. The data adapter acts as the interface between various elements of the STOLAND system and also among the system, the simulated aircraft, and other internal devices. Communication with the computer is by means of high speed parallel data transfer (18 and 36 bit). Serial data communication is used extensively to minimize interface wiring difficulties. Interfaces contained in the data adapter meet the requirements of standard ARINC characteristics 547 (VHF/NAV receivers), 552 (radio altimeter), 568 (DME), and 561 (INS), as well as MLS receiver equipment which falls under the research or prototype category.

A key element of the STOLAND simulator is the airborne hardware simulator (AHS), which provides an exact electrical interface for all airborne sensors and subsystems that interface with the data adapter. The serial data is decoded, stored, and transmitted to the 1819A computer by circuit elements within the data adapter. The AHS allows an exact duplication of all airborne data traffic that would enter and leave the STOLAND computer complex in a flight situation. The hardware interfaces of the data adapter are thoroughly exercised by this procedure, and all of the computer's software--for input/output, data acquisition, and analog/digital conversion--is validated. To the extent that the entire real time data flow is exactly duplicated, a validation run in the simulator is a true representative of a real flight, insofar as the avionics computer complex is concerned.

Both the STOLAND ground-based simulator and the airborne system are equipped with command (i.e., Electronic Attitude Director Indicator - EADI) and monitoring (i.e., Multifunction Display - MFD) displays. These displays can be advantageously used to provide the research pilot with adequate information regarding the performance of the avionics system.

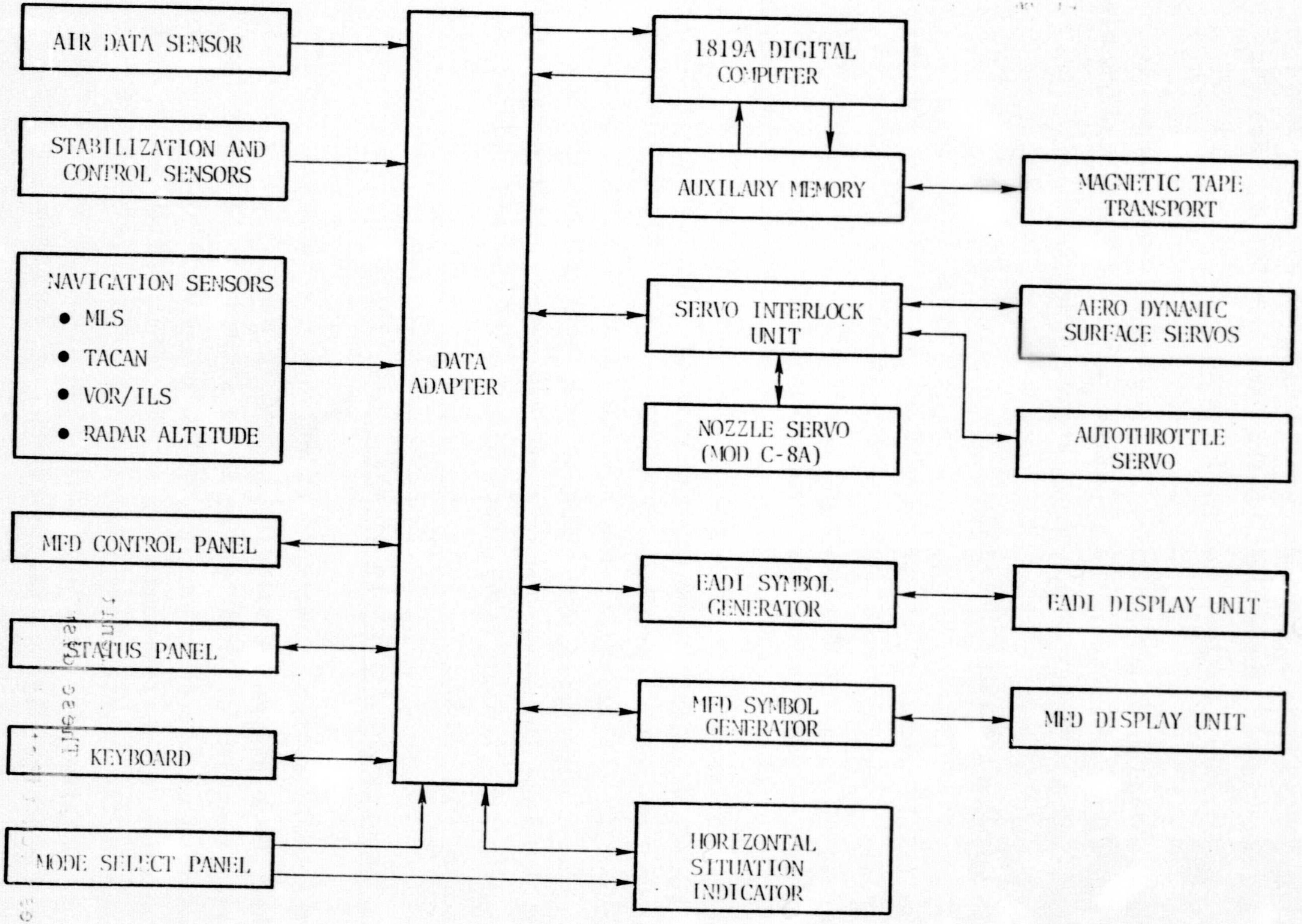


FIGURE 3.3: STOLAND BLOCK DIAGRAM

The STOL aircraft simulated is a prototype version of the DeHavilland DHC-5. This aircraft was designated DV-7A by the U.S. Army and later redesignated C-8A by the U.S. Air Force. See Fig. 3.4 for the various physical and performance specifications [1].

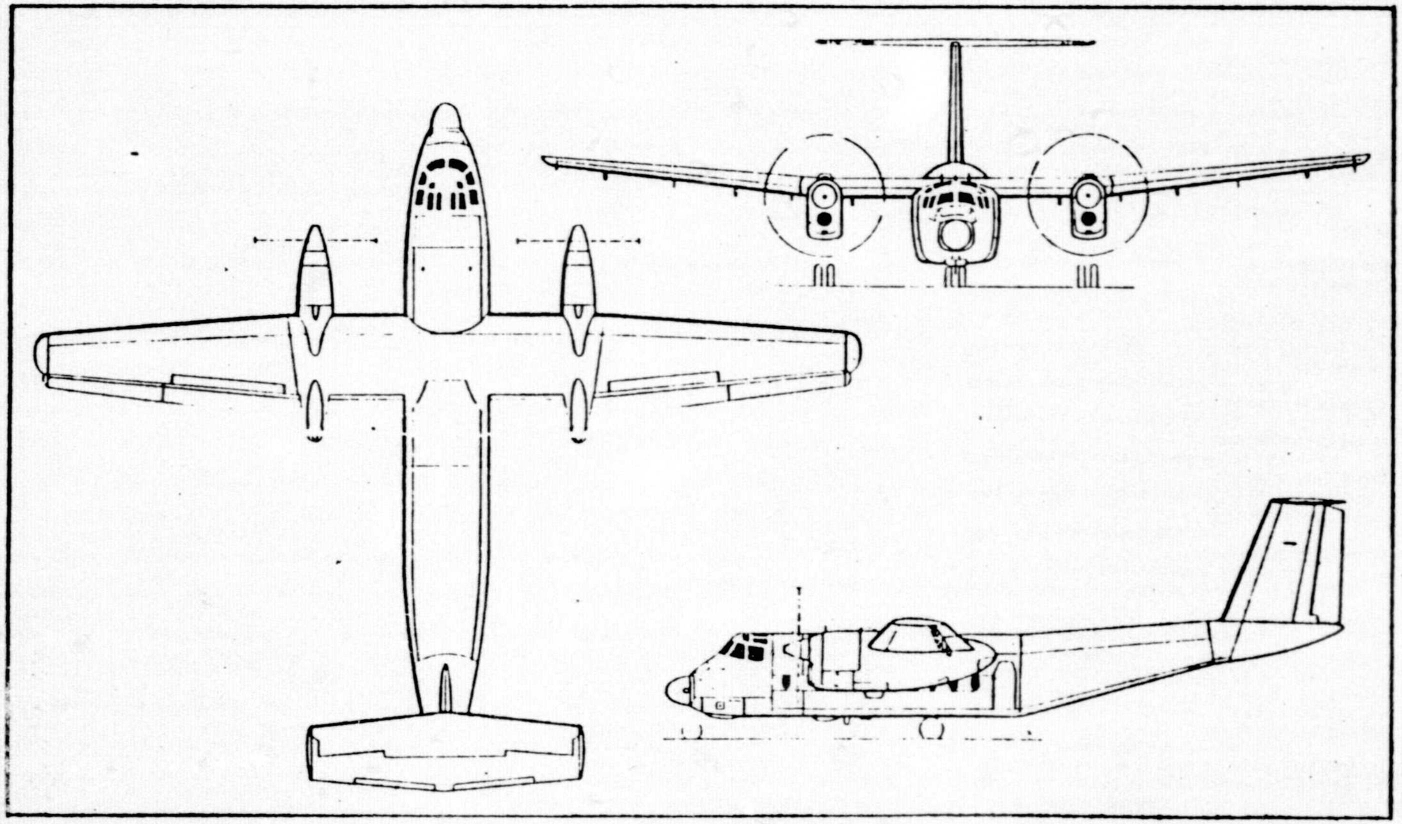
The simulation model includes the six degree-of-freedom nonlinear equations of motion, the kinematic and nonlinear aerodynamic equations, and a GET64-10 turbo-prop engine model.

3.2 TSS VERSION OF THE SIMULATION

The TSS 360 version of the simulation is essentially similar to the real time simulation with the exception that presently it can operate only in the full automatic mode (i.e., all manual/mode commands are entered before the simulation is started). Like the real time simulation, the 360 version consists of two major modules. One module corresponds to the program that was in the 1819A computer, for navigation, guidance, and control. The other module is composed of the set of programs that were in the 8400 computer for simulating the C-8 aircraft, the MLS and TACAN (VOR/DME) navigation signals, with noise error models and the environment. On the 360 version, these two modules are run under an executive called "BASIC DRIVER." A high level block diagram of the 360 simulation is shown in Fig. 3.5.

3.2.1 Concepts and Structure of the BASIC System

The BASIC system, developed under separate contract, groups together those processes basic or common to most flight simulations. The major function of this system is to provide a structure for the solution of the equations of motion for a rigid-body vehicle. The equations of motion contained in the BASIC system are a modified set of the Fogerty-Howe equations [2] shown in Fig. 3.6. Detailed information regarding these equations, as well as the kinematics of the digital BASIC system, are contained in Ref. 6.



DHC-5 Buffalo twin-turboprop STOL utility transport

FIGURE 3.4: DESCRIPTION OF THE C-8A (CV-7A)

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DHC-5 Buffalo STOL utility transport

Differences between the US and Canadian versions are as follows:

CV-7A. US model, with 2,850 eshp General Electric T64/GE-10 turboprops. Overall length 77 ft 4 in (23·57 m).

CC-115. Canadian Defence Force model, with 3,055 eshp General Electric T64/P2 turboprops. Overall length 79 ft 0 in (24·08 m). Otherwise similar to CV-7A, with only small differences in performance.

WINGS: Cantilever high-wing monoplane. Wing section NACA 64₁A417·5 (mod) at root, NACA 63₂A615 (mod) at tip. Aspect ratio 9·75. Chord 11 ft 9½ in (3·59 m) at root, 5 ft 11 in (1·19 m) at tip. Dihedral 0° inboard of nacelles, 5° outboard. Incidence 2° 30′. Sweepback at quarter-chord 1° 40′. Conventional fail-safe multi-spar structure of high-strength aluminium alloys. Full-span double-slotted aluminium alloy flaps, outboard sections functioning as ailerons. Aluminium alloy slot lip spoilers, forward of inboard flaps, are actuated by Jarry Hydraulics unit. Spoilers coupled to manually-operated ailerons for lateral control, uncoupled for symmetrical ground operation. Electrically-actuated trim-tab in starboard aileron. Geared tab in each aileron. Rudder-aileron interconnect tab on port aileron. Outer wing leading-edges fitted with electrically-controlled flush pneumatic rubber de-icing boots.

FUSELAGE: Fail-safe structure of high-strength aluminium alloy. Cargo floor supported by longitudinal keel members.

TAIL UNIT: Cantilever structure of high-strength aluminium alloy, with fixed-incidence tailplane mounted at tip of fin. Elevator aerodynamically and mass-balanced. Fore and trailing serially-hinged rudders are powered by tandem jacks operated by two independent hydraulic systems manufactured by Jarry Hydraulics. Trim-tab on port elevator, spring-tab on starboard elevator. Electrically-controlled flush pneumatic rubber de-icing boot on tailplane leading-edge.

LANDING GEAR: Retractable tricycle type. Hydraulic retraction, nose unit aft, main units forward. Jarry Hydraulics oleo-pneumatic shock absorbers. Goodrich main wheels and tyres, size 37·00 × 15·00-12, pressure 45 lb/sq in (3·16 kg/cm²). Goodrich nose wheels and tyres size 8·90 × 12·50, pressure 38 lb/sq in (2·67 kg/cm²). Goodrich multi-disc brakes.

POWER PLANT: Two General Electric T64 turboprop engines (details under entries for individual versions, above), each driving a Hamilton Standard 63E60-13 three-blade propeller, diameter 14 ft 6 in (4·42 m). Fuel in one integral tank in each inner wing, capacity 533 Imp gallons (2,423 litres) and rubber bag tanks in each outer wing, capacity 336 Imp gallons (1,527 litres). Total fuel capacity 1,738 Imp gallons (7,900 litres). Refuelling points above wings and in side of fuselage for pressure refuelling. Total oil capacity 10 Imp gallons (45·5 litres).

DIMENSIONS, EXTERNAL:

Wing span	96 ft 0 in (29·26 m)
Length overall:	
CV-7A	77 ft 4 in (23·57 m)
CC-115	79 ft 0 in (24·08 m)
Height overall	28 ft 8 in (8·73 m)
Tailplane span	32 ft 0 in (9·75 m)
Wheel track	30 ft 6 in (9·29 m)
Wheelbase	27 ft 11 in (8·50 m)
Cabin doors (each side):	
Height	5 ft 6 in (1·68 m)
Width	2 ft 9 in (0·84 m)
Height to sill	3 ft 10 in (1·17 m)
Emergency exits (each side, below wing leading-edge):	
Height	3 ft 4 in (1·02 m)
Width	2 ft 2 in (0·66 m)
Height to sill approx	5 ft 0 in (1·52 m)
Rear cargo loading door and ramp:	
Height	20 ft 9 in (6·33 m)
Width	7 ft 8 in (2·33 m)
Height to ramp hinge	3 ft 10 in (1·17 m)

DIMENSIONS, INTERNAL:

Cabin, excluding flight deck:	
Length, cargo floor	31 ft 5 in (9·58 m)
Max width	8 ft 9 in (2·67 m)
Max height	6 ft 10 in (2·08 m)
Floor area	243·5 sq ft (22·63 m²)
Volume	1,715 cu ft (48·56 m³)

AREAS:

Wings, gross	945 sq ft (87·8 m²)
Ailerons (total)	39 sq ft (3·62 m²)
Trailing-edge flaps (total, including ailerons)	280 sq ft (26·01 m²)
Spoilers (total)	25·2 sq ft (2·34 m²)
Fin	92 sq ft (8·55 m²)
Rudder, including tab	60 sq ft (5·57 m²)
Tailplane	151·5 sq ft (14·07 m²)
Elevators, including tab	81·5 sq ft (7·57 m²)

WEIGHTS AND LOADINGS:

Operating weight empty, including 3 crew at 200 lb (91 kg) each, plus trapped fuel and oil and full cargo handling equipment	23,157 lb (10,505 kg)
Max payload	13,843 lb (6,279 kg)
Max T-O weight	41,000 lb (18,598 kg)
Max zero-fuel weight	37,000 lb (16,783 kg)
Max landing weight	39,000 lb (17,690 kg)
Max wing loading	43·4 lb/sq ft (212 kg/m²)
Max power loading	7·2 lb/eshp (3·27 kg/eshp)

PERFORMANCE (CV-7A, at max T-O weight):

Max level speed at 10,000 ft (3,050 m)	271 mph (435 kmh)
Max permissible diving speed	334 mph (537 kmh)
Max cruising speed at 10,000 ft (3,050 m)	271 mph (435 kmh)
Econ cruising speed at 10,000 ft (3,050 m)	208 mph (335 kmh)
Stalling speed, 40° flaps at 39,000 lb (17,690 kg) AUW	75 mph (120 kmh)
Stalling speed, flaps up at max AUW	105 mph (169 kmh)
Rate of climb at S/L	1,890 ft (575 m) min
Service ceiling	30,000 ft (9,150 m)
Service ceiling, one engine out	14,300 ft (4,360 m)
T-O run on firm dry sod	1,040 ft (317 m)
T-O to 50 ft (15 m) from firm dry sod	1,540 ft (470 m)
Landing from 50 ft (15 m) on firm dry sod	1,120 ft (342 m)
Landing run on firm dry sod	610 ft (186 m)
Range with max fuel and 4,000 lb (1,815 kg) payload, with allowances for warm-up, taxying, take-off, climb, descent and 45 min reserve at cruise power	2,170 miles (3,490 km)
Range with max payload, reserves as above,	507 miles (815 km)

FIGURE 3.4: CONCLUDED

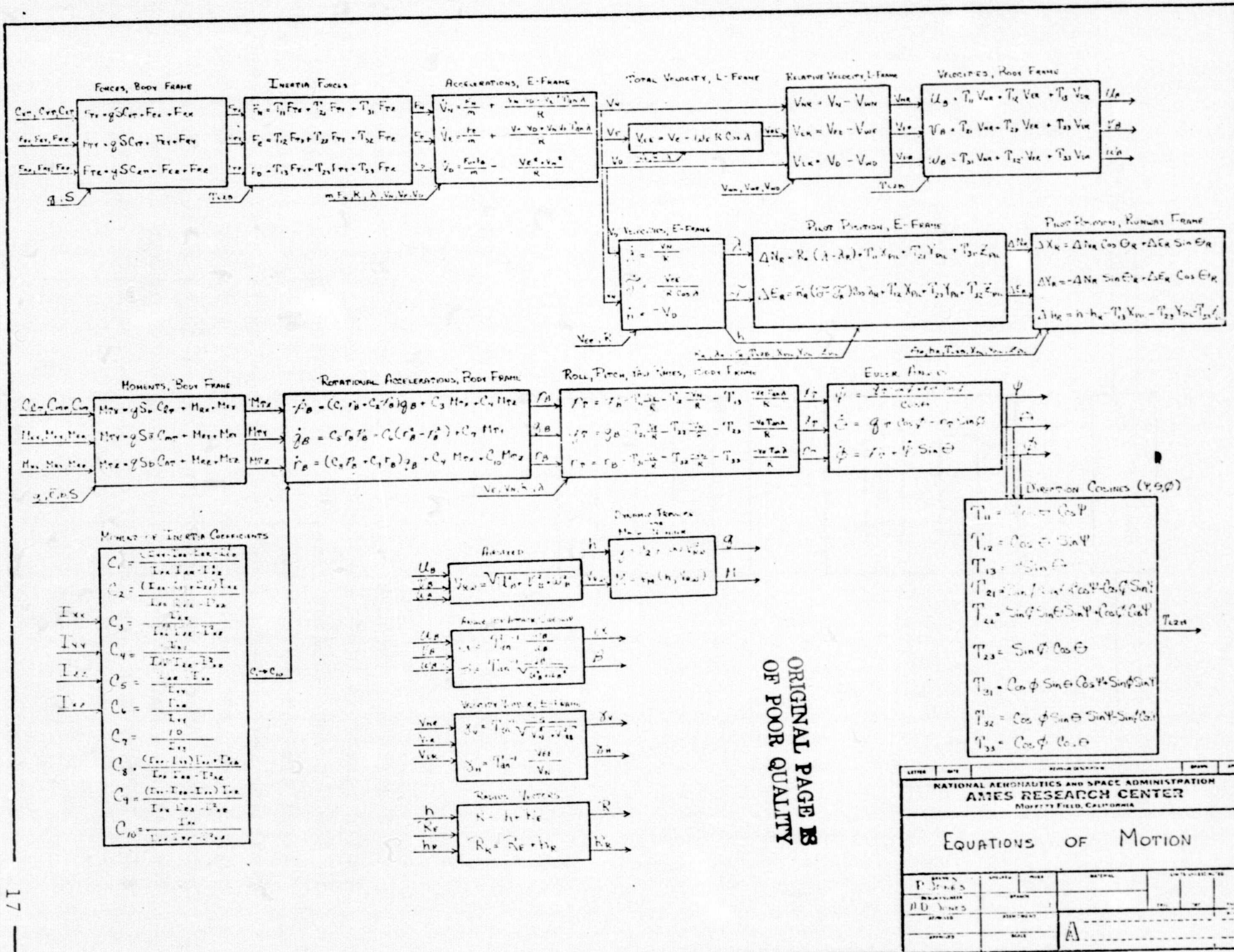

FIGURE 3.6: FOGARTY-HOWE EQUATIONS OF MOTION

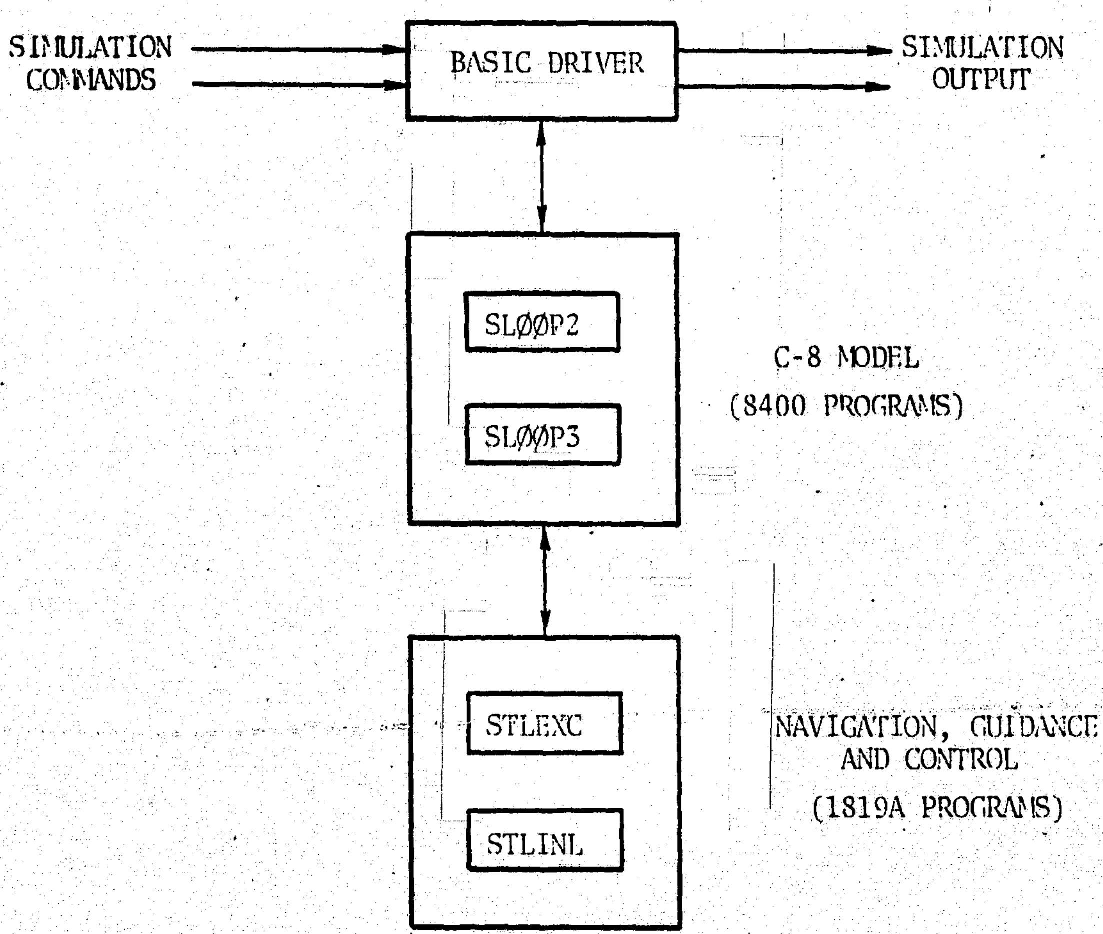

FIGURE 3.5: BLOCK DIAGRAM OF 360 SIMULATION

Figures 3.7 through 3.10 [4] illustrate the flow of execution (solid lines) in LØØP2 and LØØP3 and the updating frequency of data in BASIC common (dotted lines). The equations appearing in these figures are those used within the subroutines LØØP2 and LØØP3. The remaining set of BASIC equations contained in the BASIC subroutines called from LØØP2 and LØØP3 (e.g., BROTATE, BTRANSFØ,...,etc.) are not shown. A more detailed description of these subroutines and the complete set of BASIC utility routines contained in the LIB. BASIC library under the FSGCET account may be found in Ref. 3.

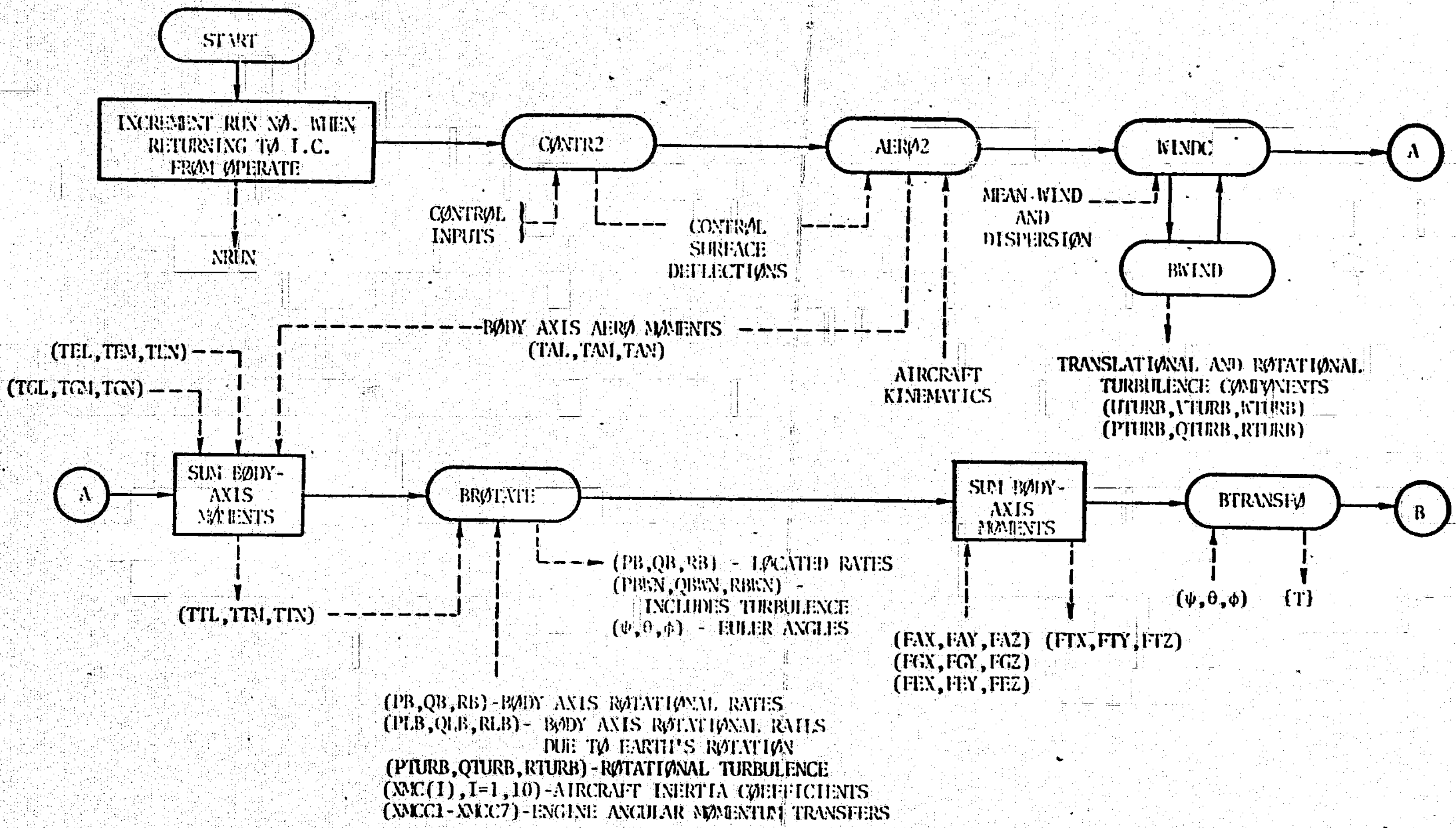

FIGURE 3.7: LØØP2 FLØW

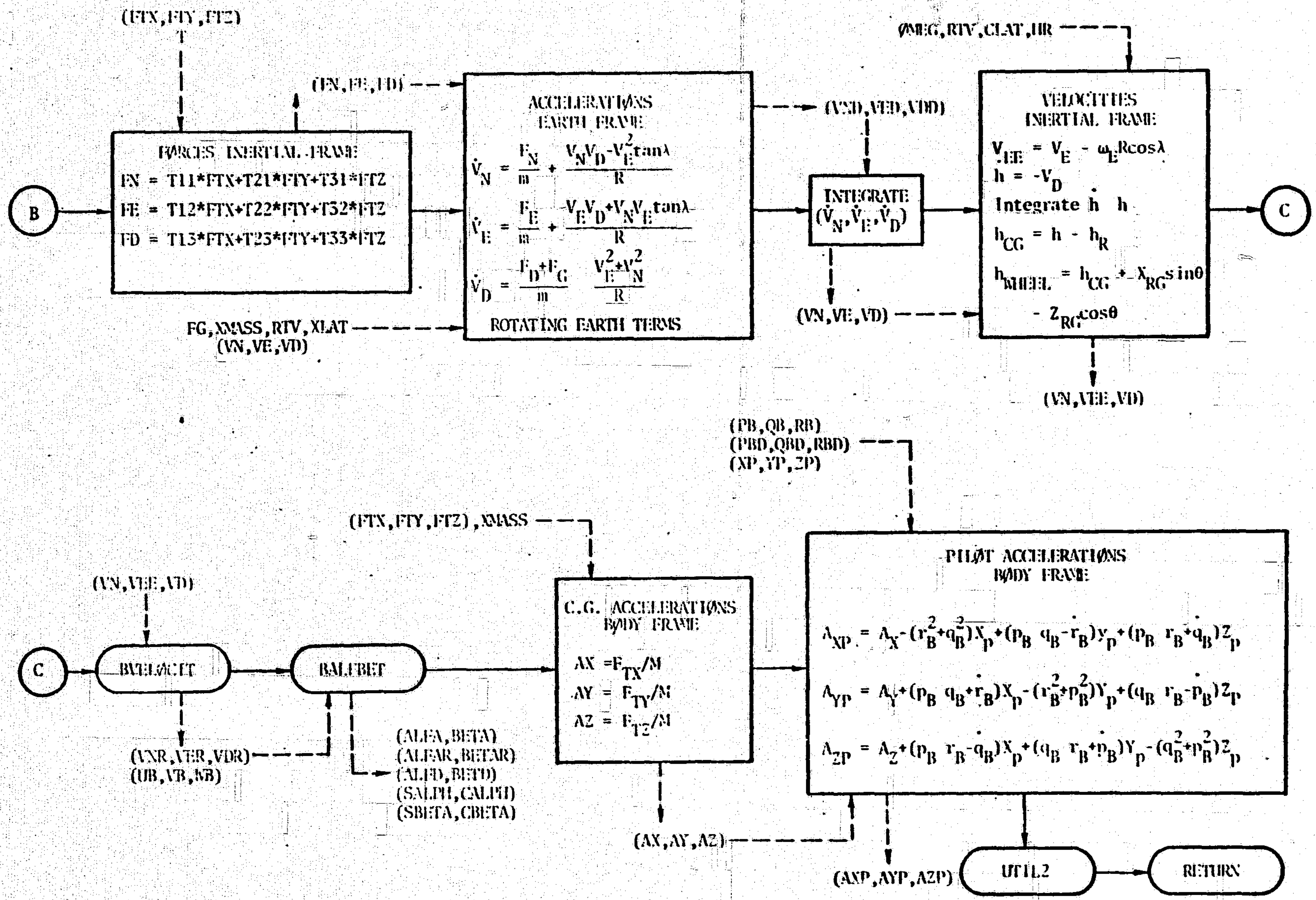

FIGURE 3.8: LØØP2 FLØW (CONTINUED)

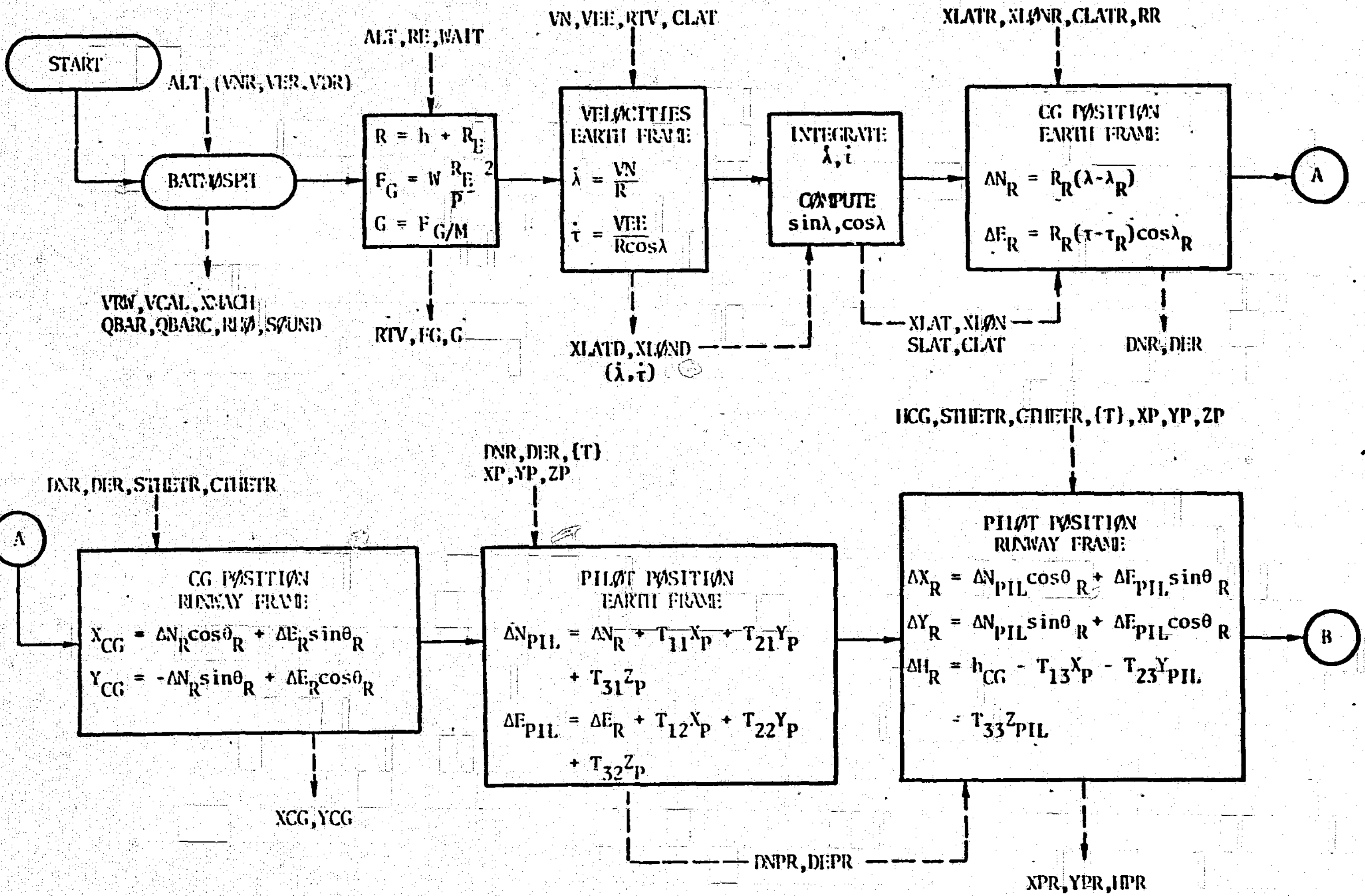

FIGURE 3.9: LØØP3 FLØW

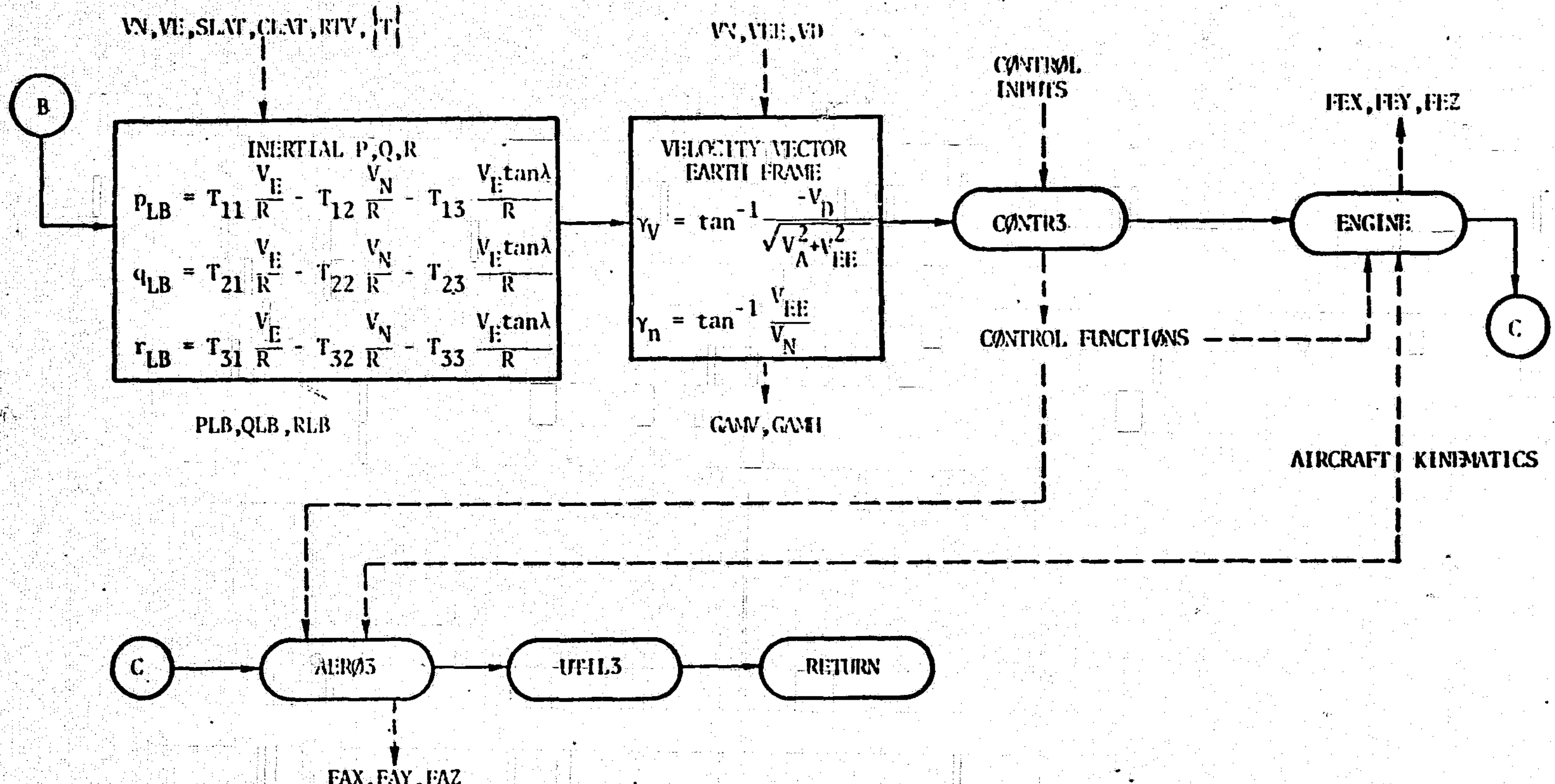

FIGURE 3.10 LØØP3 FLØW (Cont'd)

The BASIC common is separated into two blocks. The XFLØAT, A(500), block is reserved for floating point parameters and the IFIXED, IA(200), block is reserved for fixed point parameters.

3.2.2 Aircraft Dependent Routines

The aircraft model, developed under separate contract [4], consists of routines CØNTR2, CØNTR3, AERØ2, AERØ3, and ENGINE. These are called by BASIC subroutines SLØØP2 and SLØØP3. A brief description of subroutines called by SLØØP2 follows:

CØNTR2: Model of the high frequency portions of the aircraft control system (i.e., of the elevator control system where CØNTR2 accepts auto-pilot elevator commands and outputs elevator deflections).

AERØ2: Model of the high frequency portions of the aircraft aerodynamics (i.e., the pitching moment model where AERØ2 accepts control surface deflections and aircraft kinematic data and outputs aerodynamic moments).

WINDC: Model of the mean winds or shears and turbulent dispersions, in the model. WINDC accepts altitude and outputs the corresponding magnitude and direction of the mean wind and supplies the standard deviation value to be used by BWIND (BASIC subroutine called by WINDC) to generate the turbulence components for use in the aircraft kinematics.

UTIL2: Interfaces with the navigation, guidance and control portion of the simulation (1819A package). Performs trimming and dynamic checks.

Routines called in SLØØP3 are:

CØNTR3: Model of the low frequency portions of the aircraft control system; this includes a model of the flap control where CØNTR3 accepts flap commands and outputs flap deflection.

ENGINE: Model of the GET 64-10 turbo-prop engine; the model accepts throttle position and outputs thrust levels.

AERØ3: Model of the low frequency portions of the aircraft aerodynamics. It includes the lift model where AERØ3 accepts control surface deflections and aircraft kinematic data and outputs aerodynamic forces.

The corresponding aircraft dependent parameters are listed in Appendix A.

Other subroutines called by DRIVER are:

SETUP: Initialization routine which establishes the starting (or I.C.) values of the user's parameters. The BASIC subroutine BSETUP is called from SETUP to establish initial conditions (I.C.) for the BASIC parameters.

UDATA: Subroutine to input data to the user common blocks.

PRINT: Subroutine to print data pertinent to the initial conditions of the simulation (see Chapter IV). It calls the BASIC subroutine BICPRINT [4] from the subroutine PRINT.

It should be noted that the Block Data routine EBLØCK$$ must be loaded prior to the execution of a BASIC simulation to provide default values for the parameters in BASIC common.

3.3 SHARP AVIONICS IMPLEMENTATION

The Sperry C-8 avionics program was converted to the corresponding fixed-point FORTRAN program. A one-to-one correspondence has been maintained between the two programs. For example, the labels in SHARP differ from those in STOLAND in that they begin with "I". Consequently, all STOLAND documentation is usable for SHARP. Table 3.1 summarizes the routines that were converted from STOLAND to SHARP. Table 3.2 lists the subroutine names in the navigation program NAVCØM, residing in bank 4 of the Sperry avionics program.

TABLE 3.1: STOLAND SUBROUTINES CONVERTED TO THE 360 VERSION

BANK		SUBROUTINE
0	N	Assigned for registers, etc. (128 NDRO)
	Y	Executive
	N	EXUTIL utility (Sim. STOLAND only)
1	Y	Autopilot executive
	N	Roll Flight Director
	Y	SAS (roll and yaw SAS)
	Y	Roll Autopilot
	Y	Pitch SAS
	Y	Pitch Autopilot
	Y	Reversion Checking (between modes)
	Y	Autothrottle
	Y	Flap Control
	N	EADI
	Y	4/D Autopilot
2	Y	Data Reduction and I/O
	N	HSI
	N	Keyboard
	N	MSP (button lights, slew switches)
	Y	Mode Interlocks
	N	Mag Tape Output
	N	Monitors and Diagnostics
3	Y	Sq. Root, Arctan, Sin, Cos, etc.
	Y	I/O Buffers, Variable Data, and
	Y	Constant Data (2048 NDRO)
4	Y	Navigation
	Y	Air Data
	Y	Integrators and Limiters
5	Y	Reference Trajectory Data
	N	DDAS
	Y	Output to 8400
	N	Line Printer Output
	N	Service Subroutines
	Y	4D Guidance
6	N	MFD Processing and Data
7	N	BITE (1024 NDRO)
	N	Preflight Tests

NOTATION: Y - Yes
N - No

TABLE 3.2: STOLAND NAVIGATION ROUTINES CONVERTED TO THE 360 VERSION

NAVCOM$$
AIRACC$$
AUTONV$$
COMFIL$$
DIRCOS$$
FRMTO$$
ILSWND$$
INERAC$$
INERGM$$
MLSTRY$$
MODOFF$$
NAVOFF$$
SBILS$$
SBLGSN$$
TACAN$$
TACTRY$$
TESXAN$$
VHFILS$$
VLDNAV$$
VORDME$$
VORTAC$$
VORTRY$$
WIND$$

As in the real time simulation, the 360 version of the 1819A program uses integer arithmetic, and the same scale factors are used for variables to simulate the actual conditions. The program structure is exactly like the 1819A assembly language program structure, and variable names are also kept the same. This aids in incorporating modifications into the 1819A avionics program that have been checked out on the 360 version.

The 360 version of the 1819 main program is called STLEXC, short for STOL EXECUTIVE. The flow diagram for STLEXC is shown in Fig. 3.11. The name in parenthesis in each block is the subroutine name. A brief description of each block follows:

(1) The INPUT subroutine is used for scaling the variables which are picked up from the 8400 part of the simulation (BASIC), such as barometric altitude. It also checks if touchdown altitude is reached and sets a flag to terminate the simulation.

(2) One second and 100 millisecond flags are updated and reset.

(3) The G4DBEG subroutine does 4D guidance computations (Sperry version). Five times every second the reference speed is computed, using the position error in the 4D trajectory. Once every 10 seconds the phantom position is updated, and times of arrival at different waypoints are recomputed. All computations are done in one pass. This is different from the 1819A, where computations are done parasitically over more than one cycle.

(4) The INTEGN subroutine performs unity gain integration, and INTEGC performs 1/10 gain integration.

(5) The MODEIL subroutine sets up conditions for switching to different commanded modes. In a real time simulation, a command is entered by pressing a button on the Mode Select Panel. In the 360, the pressing of a button corresponds to setting a particular entry in array ID(I).

(6) The NAVCOM subroutine checks to see if navigation signals are valid and selects the best Navaid. It does dead-reckoning if the navigation signals are not valid.

(7) The APEXEC subroutine checks for pitch arm, pitch engage, roll arm, and roll engage flags. It arms or engages the required longitudinal or lateral auto-pilot mode (control law). It also checks for auto-throttle modes and calls the stability augmentation subroutines.

The aircraft/avionics interface is defined in subroutines UTIL2 and INPUT. The variables exchanged and scaled in UTIL2 correspond to the actual variables exchanged between the 8400 and 1819A computers. In INPUT, certain variables such as airspeed and dynamic pressure are picked up from BASIC. Detailed parameter lists and scale factors are documented in Appendix B.

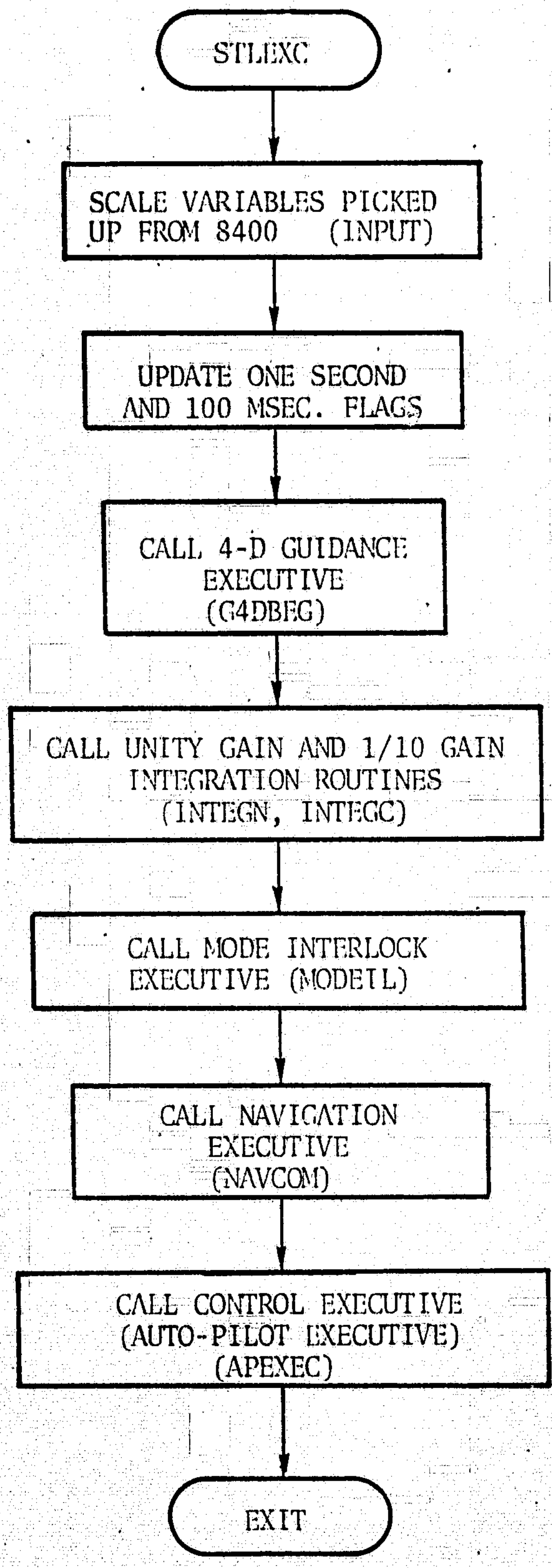

FIGURE 3.11: FLOW DIAGRAM OF STLEXC

IV. OPERATING DETAILS OF PROGRAM SHARP

In Section 4.1, the execution sequence is explained. This is followed by details of the mode utilization and selection procedure. The method of setting up decks for runs is illustrated in Section 4.3. The input/output details are described in Section 4.4. Finally, Section 4.5 states the plotting and data statistics features of the SHARP simulation.

4.1 SHARP EXECUTION SEQUENCE

Running the SHARP simulation consists of issuing different commands to the BASIC main program called DRIVER [4] shown in Fig. 4.1. First, a block data routine called EBLØCK is loaded to initialize different parameters and then DRIVER is loaded and different command are given. A list of commands and a BASIC DRIVER description are in the next section. Different versions of the simulation can be maintained in different job libraries [5]. At present, all the object modules except the navigation modules are stored in job library LIB.SIM on a private disc pack. The navigation modules are in job library LIB.MLS.

The sequence of execution is usually as follows:

(1) <u>Setting Parameter Values</u>

The first step is to change the default values of parameters to the desired values. There are two commands to change entries (default values of parameters) in CØMMØN blocks:

(a) DATA command: for changing entries in BASIC common XFLØAT and IFIXED. The parameters could be DELTRIM, VEQIC, XIC, YIC, HIC, etc.

(b) UDATA command: for changing entries in 1819A and C-8 commons (e.g., STL and BTYPE). The parameters could be the required autopilot mode, the throttle lever setting, etc.

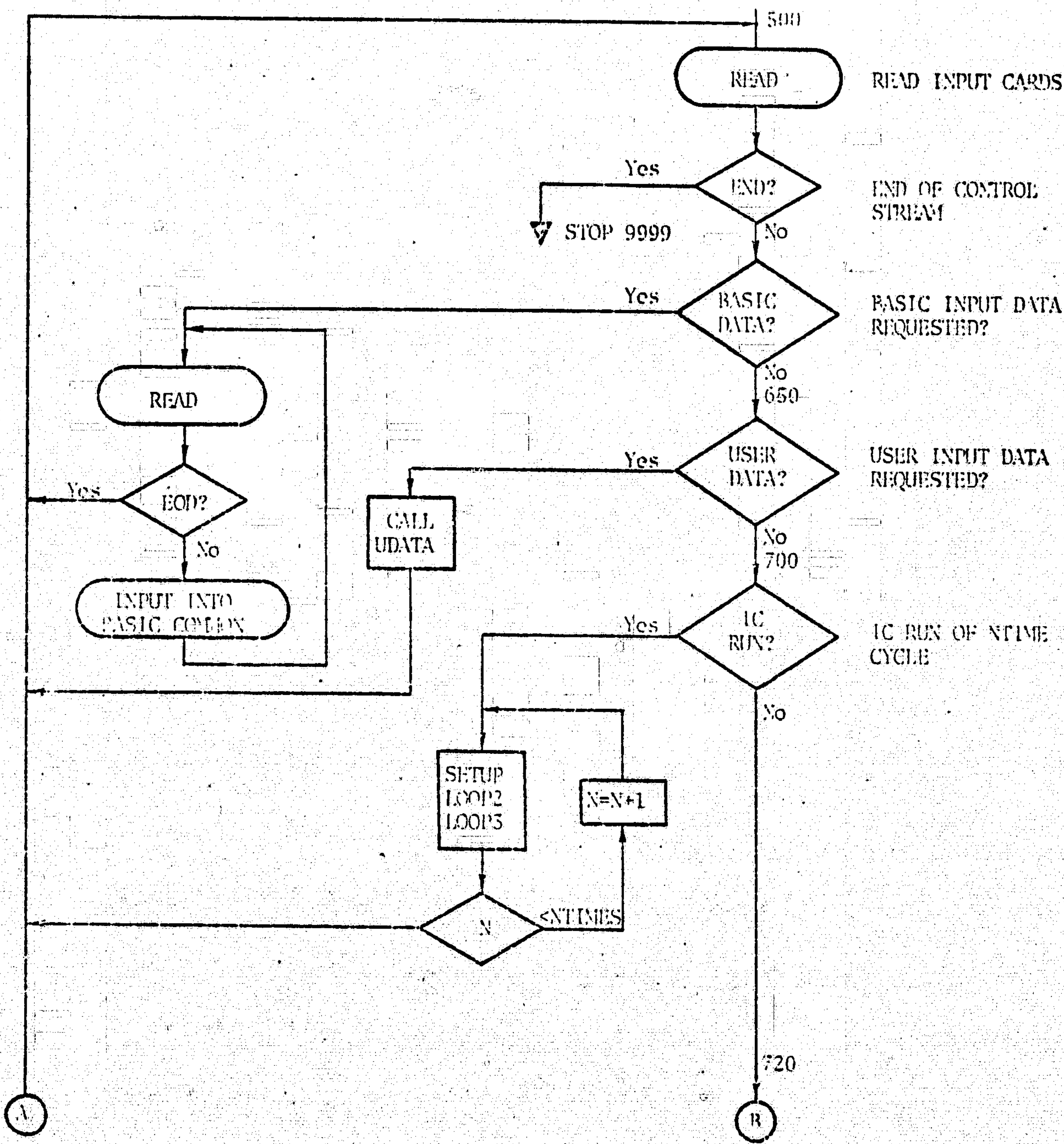

FIGURE 4.1: BASIC BATCH DRIVER FLOW CHART

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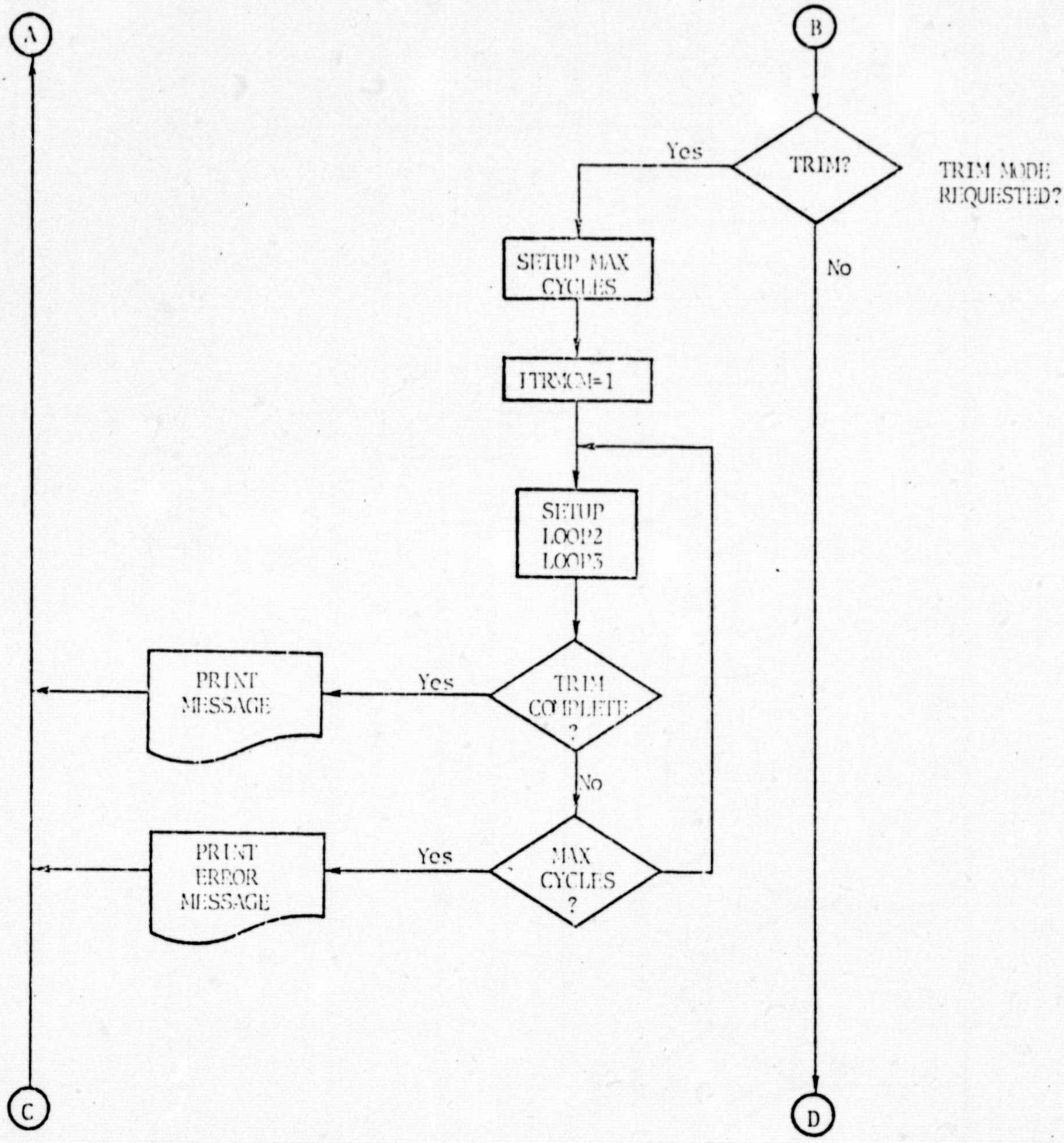

FIGURE 4.1: CONTINUED

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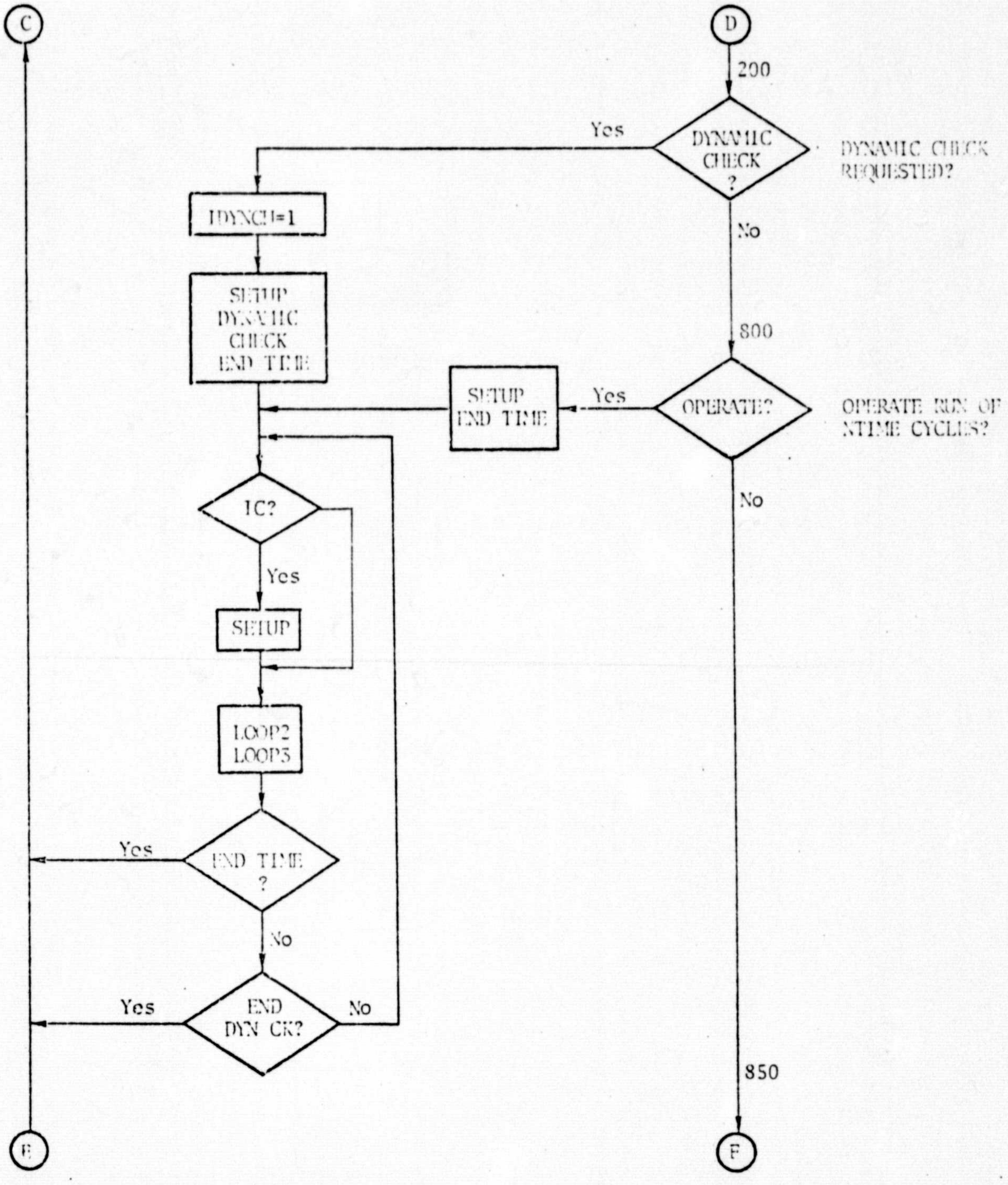


FIGURE 4.1: CONTINUED

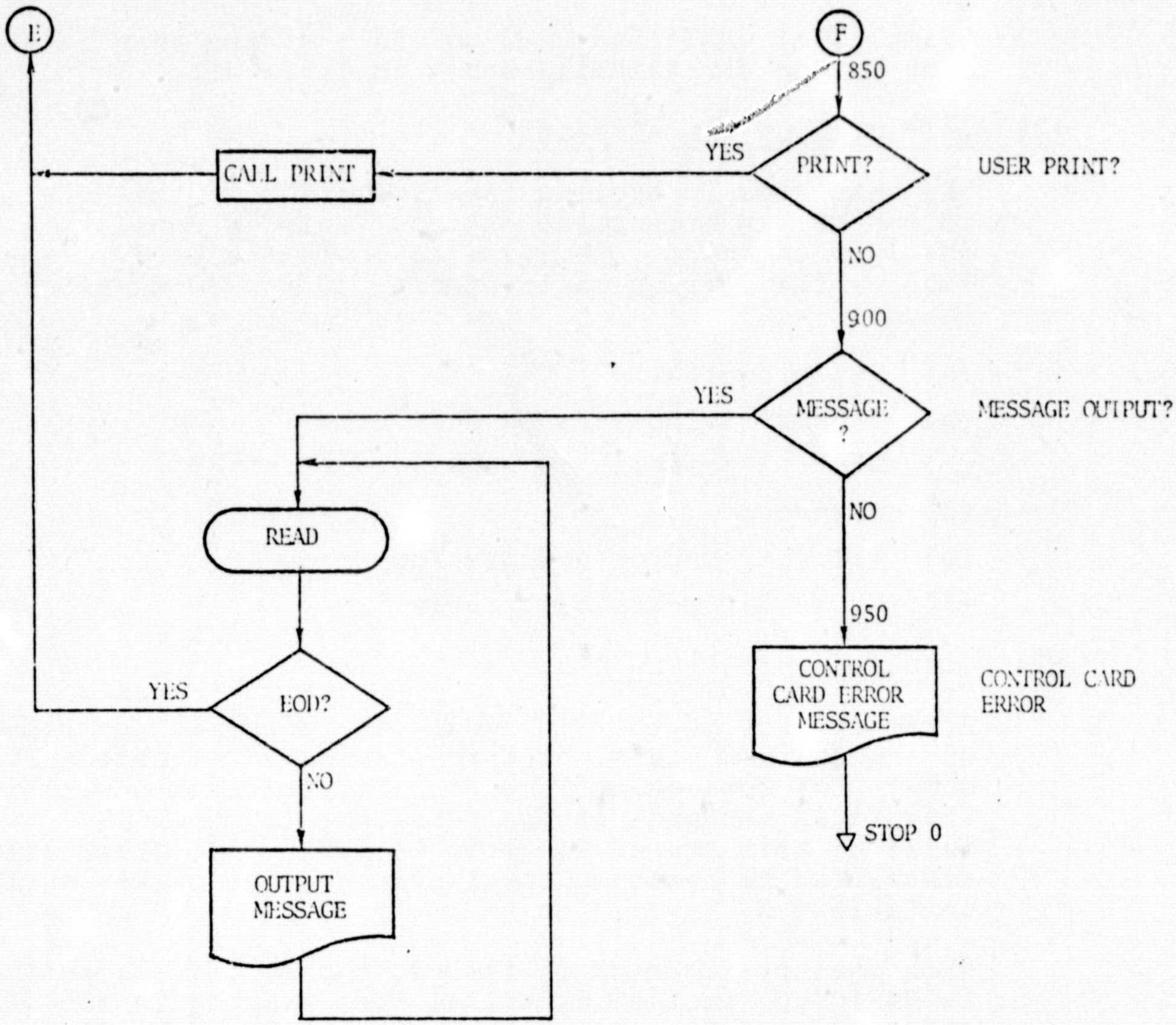


FIGURE 4.1: CONTINUED

Examples of UDATA and DATA commands can be seen in the deck set-up for trimming shown in Table 4.1.

(2) Initializing the Aircraft

The next step is cycling the simulation in the I.C. mode to ensure proper initialization. This is done by issuing the ICRN command. The state to be initialized is specified by the entries in locations 230 to 240 in BASIC common:

(a) Euler angles

(b) Angular velocities in body axes

(c) X, Y, Z position in runway coordinates

(d) Airpseed

(e) Velocity vector orientation

(f) X, Y, Z moments of inertia.

(3) Trimming the Aircraft

After cycling in the I.C. mode, the aircraft is trimmed at the desired state. Trimming needs to be done only once. For subsequent runs, the aircraft can be initialized (ICRN command) at the resultant trim state. A table of trim states is given in Table 4.2; other trim states can be found in the listing of job decks starting in Table 4.3.

When the trim command is issued, the BQUIET subroutine (a BASIC subroutine) is called for trimming in the SETUP subroutine (C-8 or 8400 subroutine). The call is of the form:

```
CALL BQUIT (NCØNT,...,DELTRIM,...,PCLP,...,THETIC,
...,DPTRIM,...,DELATT,...,PSIIC,...)
```

where:

DELTRIM: Elevator trim parameter

PCLP: Throttle position

THETIC: Euler angle

DPTRIM: Rudder trim parameter

DELATT: Aileron trim parameter

PSIIC: Euler angle

NCØNT: No. of variables to be trimmed

Dots in the subroutine argument are to indicate the trimming limits for the preceding parameters. Trimming of all six variables is not necessary, since NCØNT specifies the number of variables to be trimmed.

Table 4.1 contains a deck set-up for trimming.

(4) Operating the Aircraft

Once the aircraft is initialized at a trim state, it is ready to fly. By issuing ØPRN command to BASIC DRIVER, the simulation is cycled in the operate mode.

During the first cycle in the operate mode, the STLINL subroutine is called in UTIL2, STLINL initializes the trajectory and precomputes some trajectory parameters (WPINTZ), turns off auto-throttle, sets the standby mode of the C-8 (MØDE00) corresponding to the STANDBY button on MFD, and initializes navigation filters. In the second and following cycles of the operate mode, the STLEXC subroutine is called in UTIL2. STLEXC calls the MØDE0 subroutine in the first cycle to switch the STANDBY mode to the ON mode and to do further initialization.

The simulation continues to cycle in the operate mode until the time specified in the argument of the ØPRN command is reached.

4.2 MODE INITIALIZATION AND SELECTION

The procedure for mode selection and initialization is dealt with in this section. First, the control inputs are entered in a similar fashion as in the real time simulation. There is a one-to-one correspondence between the buttons and switches on the control panel in the cockpit and the flags in the 360 simulation. A list of these flags is given in Appendix B. At present, the following flags have been set for full auto flight:

(1) AUTO SWITCH (IDS 06)
(2) SAS SWITCH (IDS 07)
(3) AUTO THROTTLE SWITCH (IDS 08)
(4) GO AROUND BUTTON (IDS 214)

The STANDBY/ON button is internally set in the simulation when it is started. The other flags have to be set in the same sequence as the corresponding buttons are pressed in real time simulation. The pressing of a button on the Mode Select Panel in the cockpit corresponds to setting one of the discretes ID(1) - ID(16) to -1. In example 2, Cards 8 and 9 indicate that the MLS button (ID(15)) is pressed during the tenth cycle of the simulation and the FULL-AUTO (ID(2)) button is pressed in the thirtieth cycle. The command on Card 8 (QUALIFY MODEIL$$; AT 10; IF %=30; SET ID(2) = 01) means that when statement number 10 is executed the thirtieth time (i.e., the simulation completes 29 cycles), the flag for full auto mode is set. More information on QUALIFY can be found in Ref. 5.

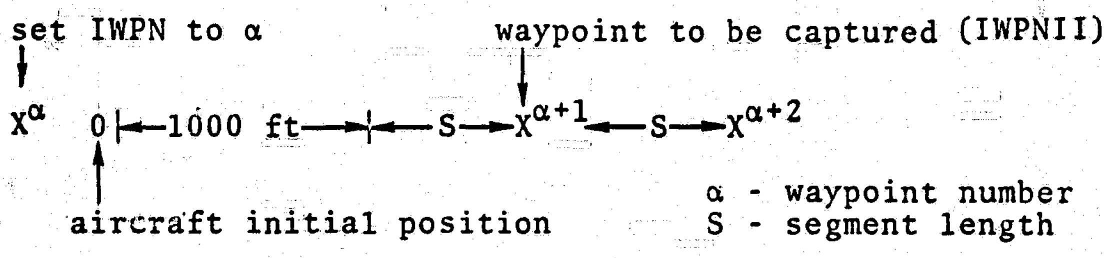
For a Monte Carlo simulation, when looping is required, the mode number and the time (or iteration number) when the mode is to be set, can be specified by initializing the array IMDSWT (2,5) which is described in Appendix B. If Mode 6 (altitude hold mode) is to be set during the tenth iteration, the array could be initialized as:

IMDSWT (1,1)	6
IMDSWT (2,1)	10

A sample deck for Monte Carlo runs has been included in the examples (Section 4.3).

For 4D guidance, to initialize the aircraft for capturing a waypoint, the following conditions should be met:

(1) The initial position should be at least a distance of 1,000 ft plus the length of the next segment behind the waypoint to be captured (see figure below):



(2) IWPN should be set to one less than the number of waypoint to be captured.

(3) The turn radii for both IWPN and the waypoint to be captured (IWPNII) should be zero (i.e., the aircraft can capture only straight segments).

The following conditions should be met for capturing the glideslope:

(1) The aircraft should be at least 600 ft above the runway, otherwise the glideslope will not be captured.

(2) The F.P.A. hold mode should be set.

The x, y, z coordinates from BASIC are used to initialize the filters in SIMIC subroutine. As the MLS EL_1 antenna is 100 ft from the threshold of the runway, the x coordinate is corrected for 100 ft to avoid the filter transients.

When the simulation operates in the 4D guidance mode, the prestored trajectory is used for guidance. The trajectory parameters are in EBLØCK block data subprogram; at present it contains the MLS trajectory. When a different trajectory is required, EBLØCK can be recompiled in another library.

When the simulation is run in the full auto mode, the best navigation aid is selected automatically. If no navigation aid is available, then dead reckoning is used.

4.3 EXAMPLE DECK SETUPS

The procedure for setting up the decks for some typical runs is illustrated in this section. Specifically, the procedure for trimming, flaring with and without the wind, 4D guidance in TACAN and MLS regions, flight path and altitude hold, go around maneuver, and the Monte Carlo option have been illustrated.

(1) Trimming

Table 4.1 is the deck set-up for trimming the aircraft. The EBLØCK subroutine is loaded (Card 6) to initialize the common blocks; then the BASIC main program driver is loaded (Card 7) and its execution is started (Card 8). The DATA command is issued to the DRIVER (Card 9) to change the default values of some parameters. The format for initializing the common blocks is described under DATA in the next section. The slash (/) in Card 17 signifies the end of the DATA command. Then the UDAT command (Card 18) is issued to initialize C-8 and 1819A commons. The slash (/) in Card 24 terminates the UDAT command.

The ICRN command (Card 25) cycles the simulation for 200 times in the I.C. mode. PRNT (Card 26 prints the results of I.C., and the TRIM command (Card 27) starts trimming at the initialized state. The final PRNT command (Card 28) prints the result of trimming, and END command (Card 29) signifies the end of the command sequence to the DRIVER routine. Typical trim states are given in Table 4.2.

(2) Initialization on Final Approach

In Table 4.3, the job deck for starting the aircraft above 600 ft on the glideslope is presented. The command sequence is the same as in the previous example, except that the ØPRN command near the bottom of the listing tells the DRIVER to cycle the simulation in the operate mode for five seconds.

(3) Initialization on Final Approach with STOLAND Wind

In Table 4.4, the job deck for starting the aircraft on the glideslope with the STOLAND wind is presented.

(4) <u>4D Guidance In TACAN Region</u>

The job deck for operating the aircraft in the TACAN region with 4D guidance is listed in Table 4.5. Note that the aircraft is initialized in the TACAN region, and the navigation package automatically selects TACAN for navigation.

(5) <u>4D Guidance in the MLS Region</u>

Table 4.6 contains the job deck for starting the aircraft in the MLS region.

(6) <u>FPA Hold, Altitude Hold, Go Around</u>

Table 4.7 contains the job deck for the Go Around mode. If the first and second QUALIFY cards in the deck were not present, the aircraft would operate in the FPA hold mode. For operating in the Altitude Hold Mode, as indicated in the job deck, common cell 1307 should be set to -1 and common cell 1309 to 0.

(7) <u>Monte Carlo Runs</u>

Table 4.8 contains a deck for Monte Carlo runs.

(8) <u>Altitude Hold, Heading Hold and Airspeed Hold</u>

In the EBLOCK subprogram, the discretes corresponding to altitude hold and heading hold modes (Appendix B-3) have been set as default autopilot modes. If the simulation is switched from I.C. to operate without setting any discretes, then the aircraft flies in altitude hold, airspeed hold and heading hold modes. The airspeed hold mode is automatically turned on as the autothrottle switch is assumed to be on.

(9) <u>Initialization on Final Approach Below 600 Ft</u>

The real time simulation checks if the aircraft is below 600 feet when the glidescope mode is aimed (subroutine PAMLS) and turns the glideslope mode off. On TSS this feature is kept, but a version of the subroutine PAMLS is compiled in library LIB.GLID where this check is not made. If the aircraft is to start below 600 feet the job deck is similar to the one shown in Table 4.4 with the addition of the following command:

JBLB LIB.GLID

(10) Changing Airspeed During Flight

The TSS simulation can be started in any of the required modes. If after x/20 seconds the airspeed is to be changed to y knots, the following TSS commands should be included in the job deck:

```
QUALIFY APEXEC$$;AT 440;IF%=X;SET IATENG=3
QUALIFY TASS$$;AT 0(1);IF%=1;SET IASPSP=Y
```

4.4 INPUT/OUTPUT DETAILS

Batch Driver

The BASIC batch driver (Fig. 4.1) is a FORTRAN program designed to control the execution of a simulation using the concepts and structure of the BASIC system. The current driver accepts nine command sets to perform program execution, BASIC data input, user designed data I/O, cycling in IC mode, cycling in operate mode, message interspersing with printout, dynamic check operations, trimming, and terminating a run session.

Each of the nine command sets are described, and the resulting action is discussed in the following paragraphs. The command sets may be in any order, and as many may appear as are required for the run session.

TABLE 4.1: EXAMPLE NO. 1

```
..RJSTART R.IOR
  LOGON FSCSCB,MATH1,235(C1),,A: IKAREEMI
MIMSG
PLEASE MOUNT DISC PACK CRSTOL
JBLE LIF.ST
LOAD EPLOCK
LOAD DRIVER
RUN DRIVER
 DATA
 1        234       72.15       VFOIC   IN KNOTS
 1        231       -5.26       THETIC
 1        235       -6.0        GAMVIC
 2         10          1        IOFEL
  1       239      -6036        XIC IN FEET
 1        240        -12        YIC IN FEET
 1        241        632        HIC IN FEET
/
 UDAT
 1         35       21.01       PCLR
 1         32       0.050       DELTR
 2         10         1.0       IDFEET
 1         18         0.0       THRCF
 1         38        40.0       SFIC
/
 ICPN                200
 PRNT                  3
 TEIN
 PRNT                  3
 END
   LOGOFF
```

TABLE 4.1 (CONTINUED): EXAMPLE NO. 1

```
              ********************************
              *                              *
              *          INPUT DATA          *
              *                              *
              ********************************
DATA INPUT TO  A(233) COMMON = 0.7215E 02          VELIC  IN KNOTS
DATA INPUT TO  A(231) COMMON = -.8260E 01          THETIC
DATA INPUT TO  A(233) COMMON = -.6000E 01          GAMVIC
DATA INPUT TO IA( 10) COMMON =          1          INFEL
DATA INPUT TO  A(239) COMMON = -.6036E 01          XIC IN FEET
DATA INPUT TO  A(240) COMMON = -.1200E 02          YIC IN FEET
DATA INPUT TO  A(241) COMMON = 0.6320E 03          HIC IN FEET
DATA INPUT TO RT (  35) COMMON =  21.00             PCLP
DATA INPUT TO RT (  32) COMMON = 0.5000E-01         DELTRM
DATA INPUT TO IR (  10) COMMON =  1.000             IDLEBT
DATA INPUT TO RT (  18) COMMON = 0.0000             TRACE
DATA INPUT TO RT (  38) COMMON =  90.00             DEIC

              ********************************
              *                              *
              *          IC RUN OF           *
              *                              *
              *         200 CYCLES           *
              *                              *
              ********************************
```

OUTPUT OF DATA AND UDAT COMMANDS (Cards 9 and 18)

ICRN COMMAND (Card 25)

TABLE 4.1 (CONTINUED): EXAMPLE NO. 1

```
                          C-8  INITIAL CONDITION PRINTOUT

RUN NUMBER        0               DATE:    06/28/78                TIME:    15:37:48

  XIXX   = 0.27[illegible]3E 06 SFT2     XIYY  = 0.2231E 06 SFT2      XIZZ  = 0.4599E 06 SFT2
  XIXZ   = 0.2950E 05 SFT2     WAIT  = 0.3264E 05 LB        CG    = 0.2730E 02
  SPAN   = 0.9600E 02 FT       CHORD = 0.1029E 02 FT        AREA  = 0.9450E 03 FT2

  DE     =-0.3923E 00 DEG.     DR    = 0.0000     DEG.      DA    = 0.0000     DEG.
  THRT   = 0.7615E 03 LBS      THS   = 0.7618E 03 LBS       CT    = 0.9134E-01
  UB     = 0.1229E 03 F/S      RCLP  = 0.2100E 02 DEG.      WB    =-0.4850E 01 F/S

  DXR    =-0.6054E 04 FT       DYR   =-0.1200E 02 FT        DHR   = 0.6347E 03 FT
  PHI    = 0.0000     DEG.     THET  =-0.8260E 01 DEG.      PSI   = 0.0000     DEG.
  ALFA   =-0.2260E 01 DEG.     BETA  = 0.0000     DEG.      GAMV  =-0.6060E 01 DEG.
  ALFD   = 0.0000     R/S      BETD  = 0.0000     R/S       GAMH  = 0.0000     DEG.

  PB     = 0.0000     R/S      QB    = 0.0000     R/S       RB    = 0.0000     R/S
  PBD    = 0.0000     R/S2     QBD   =-0.7000E-03 R/S2      RBD   = 0.0000     R/S2

  CD     = 0.3511E 00          CL    = 0.1944E 01
  CX     =-0.2[illegible]41E 00          CY    = 0.0000                 CZ    =-0.1931E 01
  CLL    = 0.0000              CLM   =-0.9620E-03           CLN   = 0.0000

  FAX    =-0.[illegible]773E 04 LB       FAY   = 0.0000     LB        FAZ   =-0.3220E 05 LB
  FEX    = 0.0000     LB       FEY   = 0.0000     LB        FEZ   = 0.0000     LB
  FGX    = 0.0000     LB       FGY   = 0.0000     LB        FGZ   = 0.0000     LB
  FTX    =-0.[illegible]773E 04 LB       FTY   = 0.0000     LB        FTZ   =-0.3220E 05 LB

  TAL    = 0.0000     LBFT     TAM   =-0.1651E 03 LBFT      TAN   = 0.0000     LBFT
  TEL    = 0.0000     LBFT     TEM   = 0.0000     LBFT      TEN   = 0.0000     LBFT
  TGL    = 0.0000     LBFT     TGM   = 0.0000     LBFT      TGN   = 0.0000     LBFT
  TTL    = 0.0000     LBFT     TTM   =-0.1651E 03 LBFT      TTN   = 0.0000     LBFT

  VN     = 0.1223E 03 F/S      VE    = 0.0000     F/S       VD    = 0.1286E 02 F/S
  VND    =-0.[illegible]533E-01 F/S2     VED   = 0.0000     F/S2      VDD   = 0.1253E 00 F/S2
  VRW    = 0.1233E 03 F/S      VEK   = 0.7220E 02 KTS       XMACH = 0.1100E 00
  VRWK   = 0.7277E 02 KTS
```

OUTPUT OF PRNT COMMAND (Card 26)

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DELTRIM = 0.050 RPMP = 993.49 RPMS = 993.49 TQTP = 152.234 TQIS = 152.234 (Card 26)

```
*********************************
*                               *
*          TRIM MODE            *
*                               *
*********************************
```

TRIM IS SUCCESSFUL AFTER 246 CYCLES (Card 27)

TABLE 4.1 (CONTINUED)

TABLE 4.1 (CONTINUED): EXAMPLE NO. 1

Card 28

```
                      C-8  INITIAL CONDITION PRINTOUT

RUN NUMBER       0           DATE:   06/24/74              TIME:    15:38:06

  XIXX  = 0.2763E 06 SFT2     XIYY  = 0.2231E 06 SFT2     XIZZ  = 0.4599E 06 SFT2
  XIXZ  = 0.2950E 05 SFT2     WAIT  = 0.3268E 05 LB       CG    = 0.2730E 02
  SPAN  = 0.9600E 02 FT       CHORD = 0.1029E 02 FT       AREA  = 0.9450E 03 FT2

  CE    =-0.9509E 00 DEG.     DP    = 0.0000     DEG.     DR    = 0.0000     DEG.
  THP   = 0.8194E 03 LBS      THS   = 0.8194E 03 LBS      CT    = 0.9826E-01
  UA    = 0.1229E 03 F/S      BCLP  = 0.2173E 02 DEG.     WS    =-0.4901E 01 F/S

  DXA   =-0.6051E 04 FT       DYA   =-0.1200E 02 FT       HHA   = 0.6587E 03 FT
  PHI   = 0.0000     DEG.     THET  =-0.4289E 01 DEG.     PSI   = 0.0000     DEG.
  ALFA  =-0.2249E 01 DEG.     BETA  = 0.0000     DEG.     GAMV  =-0.6000E 01 DEG.
  ALFD  = 0.0000     R/S      BETD  = 0.0000     R/S      GAMH  = 0.0000     DEG.

  PB    = 0.0000     R/S      QB    = 0.0000     R/S      RB    = 0.0000     R/S
  PBD   = 0.0000     R/S2     QBD   =-0.1006E-03 R/S2     RBD   = 0.0000     R/S2

  CD    = 0.3036E 00          CL    = 0.1952E 01
  CX    =-0.2822E 00          CY    = 0.0000              CZ    =-0.1938E 01
  CLL   = 0.0000              CLM   =-0.1309E-03          CLN   = 0.0000

  FAX   =-0.4719E 04 LB       FAY   = 0.0000     LB       FAZ   =-0.3233E 05 LB
  FEX   = 0.0000     LB       FEY   = 0.0000     LB       FEZ   = 0.0000     LB
  FGX   = 0.0000     LB       FGY   = 0.0000     LB       FGZ   = 0.0000     LB
  FTX   =-0.4719E 04 LB       FTY   = 0.0000     LB       FTZ   =-0.3233E 05 LB

  TAL   = 0.0000     LBFT     TAM   =-0.2243E 02 LBFT     TAN   = 0.0000     LBFT
  TEL   = 0.0000     LBFT     TEM   = 0.0000     LBFT     TEN   = 0.0000     LBFT
  TGL   = 0.0000     LBFT     TGM   = 0.0000     LBFT     TGN   = 0.0000     LBFT
  TTL   = 0.0000     LBFT     TTM   =-0.2245E 02 LBFT     TTN   = 0.0000     LBFT

  UE    = 0.1224E 03 F/S      VE    = 0.0000     F/S      WE    = 0.1266E 02 F/S
  UED   =-0.1172E-01 F/S2     VED   = 0.0000     F/S2     WED   = 0.1173E-01 F/S2
  VTA   = 0.1230E 03 F/S      VEK   = 0.7220E 02 KTS      XMACH = 0.1104E 00
  VKAS  = 0.7277E 02 KTS

DELTRIM =    0.253  RPMP = 1007.50  RPMS = 1007.50  TRIP = 159.132  TRIS = 159.132
```

TABLE 4.2: TRIM STATES

VEQIC	HIC	GAMVIC	THETIC	PCLP	DELTRIM	DFIC	IDLEBT/ IWEEL
(KNOTS)	(FEET)	DEGREES	DEGREES	DEGREES		DEGREES	
69.8	2160	0	-3.95	48.5	0.141	40	1/1
72.1	200	-6.0	-8.235	21.37	0.057	40	1/1
72.05	1271	-6.0	-8.21	22.08	0.058	40	1/1
72.05	2160	0	-4.94	49.43	0.078	40	1/1
137.1	1500	0	2.22	32.72	0.017	0	0/0
140.1	1500	0	2.01	33.73	0.034	0	0/0
212.2	3220	0	-1.17	66.8	-0.031	0	0/0
212.4	3300	-2.0	-3.17	57.90	-0.032	0	0/0
72.15	600	-6.0	-8.257	21.73	0.056	40	1/1

TABLE 4.3: EXAMPLE NO. 2

```
..RUSTART R TCB
  LOGON FSCRCH,[illegible],[illegible](5),,[illegible]
MTMSG
PLEASE [illegible] DISC PACK CASTLE
JSI - [illegible].ST
LOAD BALOCH+S
LOAD DRIVER+S
8 QUALIFY MODEL[illegible]; AT 10; IF X=30; SET IO(2) = -1
9 QUALIFY MODEL[illegible]; AT 15; IF X=10; SET IO(15) = -1
RUN DATA[illegible]
 DATA
 1      236      72.15      [illegible] IN KNOTS
 1      231      -3.25      THETIC
 1      233      -5.0       GAMMIC
 2       16         1       I[illegible]
 1      239     -4[illegible]     XIC IN FEET
 1      240       -12       YIC IN FEET
 1      241       632       HIC IN FEET
/
 UDAT
 1       35      21.75      DELP
 1       32      6.656      DELTSP
 2       16        1.0      IDLFRN
 1       18        6.[illegible]      THROF
 1       35       45.[illegible]      DFIC
 3     1307                          TURN OFF ALTITUDE HOLD MODE.
 3     1304          -1              FLIGHT PATH ANGLE HOLD MODE
/
 ICRT               20[illegible]
 PRNT                  3
 UDAT
 2        7            1             IAYOPR
/
 OPRN                5.0
 FRNT                  5
 PRNT                  [illegible]
 END
  LOGOFF
```

TABLE 4.3 (CONTINUED): EXAMPLE NO. 2

```
              ********************************
              *                              *
              *          INPUT DATA          *
              *                              *
              ********************************
DATA INPUT TO  A(238) COMMON = 0.7215E 02          VEQIC  IN KNOTS
DATA INPUT TO  A(231) COMMON = -.8260E 01          THETIC
DATA INPUT TO  A(233) COMMON = -.6000E 01          GAMVIC
DATA INPUT TO IA( 10) COMMON =          1          T-FEET
DATA INPUT TO  A(239) COMMON = -.6036E 04          XIC IN FEET
DATA INPUT TO  A(240) COMMON = -.1200E 02          YIC IN FEET
DATA INPUT TO  A(241) COMMON = 0.6320E 03          HIC IN FEET
DATA INPUT TO RT (  35) COMMON =  21.73             FCLP
DATA INPUT TO RT (  32) COMMON = 0.5600E-01         IFLTRM
DATA INPUT TO IR (  10) COMMON =  1.000             IDLFHT
DATA INPUT TO RT (  18) COMMON = 0.0000             IH CE
DATA INPUT TO RT (  35) COMMON =  40.01             DFIC
DATA INPUT TO IST(1307) COMMON = 0.0000                  TURN OFF ALTITUDE HOLD MODE.
DATA INPUT TO IST(1305) COMMON = -1.000                  FLIGHT PATH ANGLE HOLD MODE

              ********************************
              *                              *
              *          TO RUN OF           *
              *                              *
              *          200 CYCLES          *
              *                              *
              ********************************
```

TABLE 4.3 (CONTINUED): EXAMPLE NO. 2

```
                    C-5  INITIAL CONDITIONS PRINTOUT

RU [illegible]                      DATE:   06/29/7[illegible]                TIME:   15:49:02

  XIXX  = 0.2763E 06 SFT2        XIYY  = 0.2251E 06 SFT2        XIZZ  = 0.4599E 06 SFT2
  XIXZ  = 0.2950E 05 SFT2        WAIT  = 0.3268E 05 LB          CG    = 0.2730E 02
  SPAN  = 0.9600E 02 FT          CHORD = 0.1029E 02 FT          AREA  = 0.9450E 03 FT2

  DE    =-0.3993E 00 DEG.        DR    = 0.0000      DEG.       DW    = 0.0000      DEG.
  THP   = 0.3205E 03 LBS         THS   = 0.2205E 03 LBS         CT    = 0.9839E-01
  UA    = 0.1229E 03 F/S         PCLP  = 0.2173E 02 DEG.        WA    =-0.4850E 01 F/S

  DXR   =-0.6054E 04 FT          DYR   =-0.1200E 02 FT          DHR   = 0.6397E 03 FT
  PHI   = 0.0000      DEG.       THET  =-0.8260E 01 DEG.        PSI   = 0.0000      DEG.
  ALFA  =-0.2263E 01 DEG.        BETA  = 0.0000      DEG.       GAMV  =-0.6000E 01 DEG.
  ALFD  = 0.0000      R/S        BETD  = 0.0000      R/S        GAMH  = 0.0000      DEG.

  PB    = 0.0000      R/S        QB    = 0.0000      R/S        RB    = 0.0000      R/S
  PBD   = 0.0000      R/S2       QBD   = 0.7499E-03 R/S2        RBD   = 0.0000      R/S2

  CD    = 0.3094E 00             CL    = 0.1954E 01
  CX    =-0.2325E 00             CY    = 0.0000                 CZ    =-0.1990E 01
  CLL   = 0.0000                 CLM   = 0.9748E-03             CLN   = 0.0000

  FAX   =-0.4712E 04 LB          FAY   = 0.0000      LB         FAZ   =-0.3237E 05 LB
  FEX   = 0.0000      LB         FEY   = 0.0000      LB         FEZ   = 0.0000      LB
  FGX   = 0.0000      LB         FGY   = 0.0000      LB         FGZ   = 0.0000      LB
  FTX   =-0.4712E 04 LB          FTY   = 0.0000      LB         FTZ   =-0.3237E 05 LB

  TAL   = 0.0000      LBFT       TAM   = 0.1673E 03 LBFT        TAN   = 0.0000      LBFT
  TEL   = 0.0000      LBFT       TEM   = 0.0000      LBFT       TEN   = 0.0000      LBFT
  TGL   = 0.0000      LBFT       TGM   = 0.0000      LBFT       TGN   = 0.0000      LBFT
  TTL   = 0.0000      LBFT       TTM   = 0.1673E 03 LBFT        TTN   = 0.0000      LBFT

  [illegible] = 0.1223E 03 F/S   VE    = 0.0000      F/S        VD    = 0.1266E 02 F/S
  [illegible] =-0.1353E-01 F/S2  VED   = 0.0000      F/S2       VDD   =-0.2562E-01 F/S2
  [illegible] = 0.1235E 03 F/S   VEQ   = 0.7220E 02 KTS         XMACH = 0.1104E 00
  V[illegible]X = 0.7277E 02 KTS
```

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TABLE 4.3 (CONTINUED): EXAMPLE NO. 2

DELTRIP = 0.066 RPCP = 1007.81 RPHS = 1007.81 TOIP = 156.916 TOIS = 158.916

DATA INPUT TO 13 (7) COMMON = 1.000 IDYUPP

TIME	PHI	XC	THET	YC	PST	TC	ALT	GAMV	ALFA	IZ96	VRAK	TRIE	THS	IZC17
1002														
1.05	0.007	-1483.	-4.252	-3.	-0.0	-7.0	-2485.	-5.99	-2.27	-2488.0	72.76	0.000	0.821E 03	722.000
1001														
2.05	0.091	-1452.	-8.152	-3.	0.0	183.0	-2433.	-5.97	-2.17	-2436.0	72.75	-0.720	0.819E 03	722.000
3.05	0.187	-1422.	-7.953	-3.	0.0	89.0	-2383.	-5.87	-2.09	-2385.0	72.69	0.320	0.813E 03	720.000
4.10	0.244	-1391.	-7.945	-3.	0.1	51.0	-2330.	-5.50	-2.19	-2332.0	72.61	0.280	0.803E 03	720.000
5.10	0.248	-1361.	-8.054	-3.	0.1	27.0	-2261.	-5.84	-2.21	-2263.0	72.53	0.160	0.800E 03	720.000

OUTPUT OF OPRN COMMAND

TABLE 4.3 (CONTINUED): EXAMPLE NO. 2

```
                         C-5  INITIAL CONDITION PRINTOUT

RUN NUMBER        [illegible]         DATE:   06/24/74                   TIME:   15:52:15

  XIXX  = 0.2763E 06 SFT2        XIYY  = 0.2251E 06 SFT2        XIZZ  = 0.4599E 06 SFT2
  XIXZ  =-0.2950E 05 SFT2        WAIT  = 0.3260E 05 LB          CG    = 0.2739E 02
  SPAN  = 0.3600E 02 FT          CHORD = 0.1029E 02 FT          AREA  = 0.9450E 03 FT2
-------------------------------------------------------------------------------------------
  DF    =-0.[illegible]E 00 DEG.  DR    = 0.0000      DEG.       DA    =-0.3003E 00 DEG.
  THR   = 0.[illegible]E 03 LBS   THS   = 0.[illegible]E 03 LBS  CT    = 0.9633E-01
  UR    = 0.1225E 03 F/S         PCLP  = 0.2172E 02 DEG.        WR    =-0.4731E 01 F/S
-------------------------------------------------------------------------------------------
  DXR   =-0.5[illegible]E 04 FT   DYR   =-0.1146E 02 FT          DHR   = 0.5702E 03 FT
  PHI   = 0.2879E 00 DEG.        THET  =-0.8059E 01 DEG.        PSI   = 0.9653E-01 DEG.
  ALFA  =-0.2212E 01 DEG.        BETA  = 0.5542E-01 DEG.        GAMV  =-0.5842E 01 DEG.
  ALFD  =-0.[illegible]E-0[illegible] R/S  BETD  = 0.2749E-03 R/S  GAMH  = 0.1619E 00 DEG.
-------------------------------------------------------------------------------------------
  PS    =-0.3673E-03 R/S         QH    =-0.8409E-03 R/S         RH    = 0.7043E-03 R/S
  PSD   =-0.[illegible]E-03 R/S2  QSD   =-0.1160E-02 R/S2        RSD   = 0.2348E-03 R/S2

  CD    = 0.3037E 00             CL    = 0.1956E 01
  CX    =-0.2827E 00             CY    =-0.9101E-03             CZ    =-0.1993E 01
  CLL   =-0.1472E-03             CLM   =-0.1515E-02             CLN   = 0.8300E-04

  FAX   =-0.[illegible]E 04 LB    FAY   =-0.1510E 02 LB          FAZ   =-0.3225E 05 LB
  FEX   = 0.0000      LB         FEY   = 0.0000      LB         FEZ   = 0.0000      LB
  FGX   = 0.0000      LB         FGY   = 0.0000      LB         FGZ   = 0.0000      LB
  FTX   =-0.[illegible]E 04 LB    FTY   =-0.1471E 02 LB          FTZ   =-0.3225E 05 LB

  TAL   =-0.2[illegible]E 03 LBFT TAM   =-0.2567E 03 LBFT        TAN   = 0.1323E 03 LBFT
  TEL   = 0.0000      LBFT       TEM   = 0.0000      LBFT       TEN   = 0.0000      LBFT
  TGL   = 0.0000      LBFT       TGM   = 0.0000      LBFT       TGN   = 0.0000      LBFT
  TTL   =-0.2[illegible]E 03 LBFT TTM   =-0.2567E 03 LBFT        TTN   = 0.1323E 03 LBFT

  VR    = 0.[illegible]E 03 F/S   VF    = 0.3644E 00 F/S         VD    = 0.1248E 02 F/S
  VRD   =-0.[illegible]E 00 F/S2  VFD   = 0.1227E 00 F/S2        VDD   = 0.9049E-01 F/S2
  VTA   = 0.[illegible]E 03 F/S   VEQ   = 0.7262E 02 KTS         MACH  = 0.1100E 00
  VTAK  = 0.7252E 02 KTS

DELTAT = [illegible]  RPM = 1000.08  RPMS = 1000.09  TCIP = 155.823  TCIS = 155.823
```

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TABLE 4.4 : FLARE WITH STOLAND WIND (EXAMPLE NO. 3)

```
..RJSTART RRT06
  LOGON FSCSCR,MAJ[illegible],0200(0),,A; 'KAREEMI'
MTP36
PLEASE MOUNT DISC PACK CMSTOL
JBLB LIB,SIM
JBLB LIB,RLS
LOAD EMLOCASS
LOAD DRIVER**
QUALIFY MODEIL**; AT 15; IF Z=5 ; SET IU(15) = -1
QUALIFY MODEIL**; AT 10; IF Z=23; SET IU(2) = -1
RUN DRIVER**
 DATA
 1      235      72.00      VEQIC  IN KNOTS
 1      231      -7.45      THETIC
 1      234       -7.5      GAMMIC
 1      233       -6.0      GAMVIC
 1      232      -2.20      PSIIC
 2      147          1      IIQTIP,FOR TRIMMING TO BE SET IN EMLOCK
 2       10          1      IFEEL
 1      239      -5918      XIC IN FEET
 1      240        -12      YIC IN FEET
 1      241        632      HIC IN FEET
/
 UDAT
 1       32      0.009     DELTAO
 1       35      26.22     PCLP
 2       15          2            I-ICO
 1       49       0.30          VOS
 1       50     0.5236           AMAP
 2       10        1.0     ICLEAT
 1       12        0.0     TANGE
 1       35       40.0     OFIC
 1       51         0.     HBIAS
 1       52         0.     E1BIAS
 1       53         0.     E2BIAS
 1       54         0.     ABIAS
/
 ICRN              200




 PRNT                3
 UDAT
 3     1307          0              TURN OFF ALTITUDE HOLD MODE,
 3     1309         -1              FLIGHT PATH ANGLE HOLD MODE
 2        7          1              IDYNPR
/
 OPRN             70.0
 PRNT                3
 PRNT                4
 END
  LOGOFF
```

TABLE 4.5 : 4D GUIDANCE IN TACAN REGION (EXAMPLE NO. 4)

```
..RUSTART R1TOH
  LOGON FSCSCH,[illegible]1,[illegible]S0(D),,A[illegible] [illegible]
MIMSG
PLEASE MOUNT DISC PACK CASTOL
JBLG LIB,SI[illegible]
JBLG LI[illegible],ALS
LOAD PROCESS
LOAD DRIVER..
QUALIFY MODULES; AT 10 ; IF X = 10 ; SET  10(2) = -1



RUN DRIVERS;
 DATA
  1      235       72.05       VEGIC   IN KNOTS
 1       231       -4.94       THETIC
 1       232       62.70       PSIIC
 1       234        -2.7       GAMIC

 2        10           1       IWHEEL
  1      239      -13970       XIC IN FEET
 1       240      -22600       YIC IN FEET
 1       170       150.0       HR, HEIGHT ABOVE RUNWAY
  1      241        2100       HIC IN FEET
/
 UDAT
 1        35       49.45     PCLP
 1        32       0.073     DELTRN
 2        10         1.0     ICLEEL
 1        18         0.0     THRCE
 1        38        40.0     OFIC
/
 ICHN               200
 PRNT                 3
 UDAT      .
 3       144          7                 IGUIDE
 3       389          8                 IXPM
 2         7          1                 IDYNPR
/




 GPRN               4.0
 PRNT                 3
 PRNT                 4
 END
  LOGOFF
```

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TABLE 4.6 : 4D GUIDANCE IN MLS REGION (EXAMPLE NO. 5)

```
..RUSTART [illegible]
  LOGON [illegible]
MINSG
PLEASE MOUNT DISC PACK [illegible]
JOBS LIB,SI
JOBS LIB,[illegible]
JOBS LIB,[illegible]
LOAD [illegible]
LOAD DRIVER[illegible]
QUALIFY [illegible] AT 15 : IF X=10 ;  SET I[illegible](2) = -1
[illegible] DRIVER[illegible]
 DATA
  1      235      72.[illegible]      [illegible]IC  IN KNOTS
  1      231      -4.[illegible]      THETIC
  1      232      -2.7[illegible]     [illegible]SIIC
  1      23[illegible]      52.7       [illegible]IC
  2      1[illegible]          1       I[illegible]EL
  1      23[illegible]    -15[illegible]      XIC IN FEET
  1      2[illegible]     -111[illegible]     YIC IN FEET
  1      2[illegible]      21[illegible]      HIC IN FEET
/
 [illegible]
 1       35       [illegible]      [illegible]
 1       32       0.[illegible]     [illegible]
 2       1[illegible]        1[illegible].       [illegible]1, TO BE SET IN [illegible]BLOCK, USED IN SETUP
 2       1[illegible]        1.0       I[illegible]CEST
 1       1[illegible]        [illegible]      [illegible]CF
 1       3[illegible]       [illegible]      [illegible]IC
/
 [illegible]             200
 [illegible]T               3
 [illegible]
 5       1[illegible]          7             I[illegible]
 5       3[illegible]          3             I[illegible]
/
```

TABLE 4.7 : GO AROUND MANEUVER (EXAMPLE NO. 6)

```
..RJSTART RMT08
  LOGON FSCSCB,MAIN1,N60(D),,A; ' KAREEMI'
MTMSG
PLEASE MOUNT DISC PACK CRSTOL
JBLB LIB,SIM
JBLB LIB,MLS
LOAD EBLOCK$$
LOAD DRIVER$$
QUALIFY MODEILS$; AT 0(2); IF %=42;SET IDS214=0,IGAARM=0
QUALIFY MODEILS$; AT 0(1); IF %=41;SET IDS214=1,IGAARM=1,IA(109)=2160,IA(112)=0
QUALIFY MODEILS$; AT 15; IF %=3 ; SET ID(15) = -1
QUALIFY MODEILS$; AT 10; IF %=23; SET ID(2) = -1
RUN DRIVER$$
 DATA
 1        238       72.00       VEQIC   IN KNOTS
 1        231       -7.66       THETIC
 1        234        -7.3       GAMHIC
 1        233        -5.0       GAMVIC
 1        232       -2.26       PSIIC
 2        187           1       ITOMTR,FOR TRIMMING TO BE SET IN EBLOCK
 2         10           1       IWEEL
 1        239       -5824       XIC IN FEET
 1        240         -12       YIC IN FEET
 1        241         632       HIC IN FEET
/
 UDAT
 1         32       0.049     DELTPM
 1         35       26.22     PCLP
 2         13           2            IWIND
 1         49        0.30           VOS
 1         50      0.5236            AMWP
 2         10         1.0     IOLEBT
 1         18         0.0     THMCR
 1         38        40.0     DFIC
 1         51          0.     RBIAS
 1         52          0.     E1BIAS
 1         53          0.     E2BIAS
 1         54          0.     ABIAS
/
 ICRN                 200




                                            For Alt. Hold Mode, Set: 1307 to -1
 PRNT                   3                                            1309 to  0
 UDAT
 3       1307           0                   TURN OFF ALTITUDE HOLD MODE,
 3       1309          -1                   FLIGHT PATH ANGLE HOLD MODE
 2          7           1                   IDYNPR
/
 OPRN                15.0
 PRNT                   3
 PRNT                   4
 END
  LOGOFF
```

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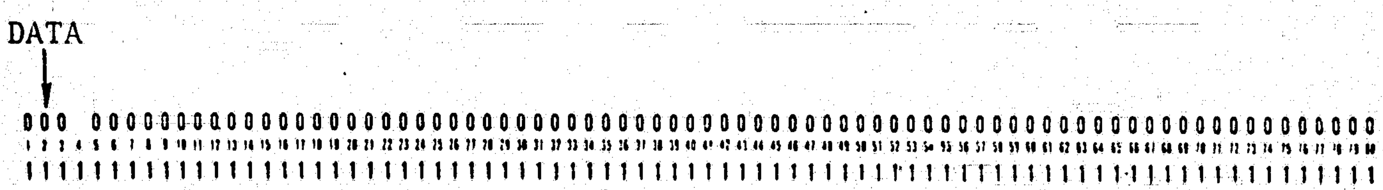
TABLE 4.8 : TYPICAL MONTE CARLO DECK SETUP (EXAMPLE NO. 7)

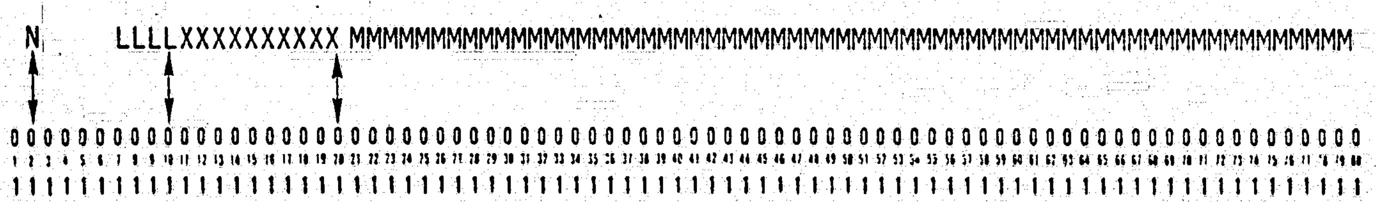
```
..RJSTART RMT08
  LOGON FSCSC5,MAIN1,N05(0),,AT 'KAREEMI'
MTMSG
PLEASE MOUNT DISC PACK CSSTOL
JOBS LIB,SIM
JOBS LIB,MLS
JOBS LIB,MCARLO
JOBS LIB,DRIVE
LOAD EBLOCKS$
LOAD DRIVER$$



RUN DRIVER$S
 DATA
  1      238      72.05      VEWIC   IN KNOTS
 1       231      -4.94      THETIC
 1       232      82.70      PSIIC
 1       234       82.7      GAMMIC
 2        10          1      IMERL
  1      239     -15856      XIC IN FEET
 1       240     -11100      YIC IN FEET
  1      241       2100      HIC IN FEET
/
 UDAT
 1        55      49.43     PCLP
 1        32      0.078     DELTRM
 2        10        1.0     ICLRST
 1        18        0.0     TRACE
 1        36       40.0     OFIC
/
 ICRN              200
 PRNT                3
 UDAT
 3      1519         0             TURN OFF HDG HOLD MODE (DEFAULT)
 3      1507         0             TURN OF ALTITUDE HOLD MODE (DEFAULT)
 3      1296         1             N, ITERATION NO, TO BE SET IN EBLOCK
 3      1277         1             K, POINT ALONG TIME AXIS.INITIAL VALUE
 3       141         7             IGROUP
 3       549         3             INPH
 3      1525         2             IND(1,1)     FULL AUTO     MODE1
 3      1526         2             IND(2,1)     CYCLE A
 1        51        0.        RBIAS
 1        52        0.        E1BIAS
 1        53        0.        E2BIAS
 1        54        0.        ABIAS
 2         7          1            IDYNPR
/
 OPRN               4.
 PRNT                4
 ICRN              200
 PRNT                3
 OPRN               4.
 PRNT                4
 ICRN              200
 PRNT                3
 OPRN               4.
 PRNT                4
 END
  LOGOFF
```

Basic Data Input

The first card of the deck is:



Following this card are the data cards required to enter data into the BASIC common blocks, XFLØAT and IFIXED. The form of these cards is:



where

N = 1 indicates XFLØAT common

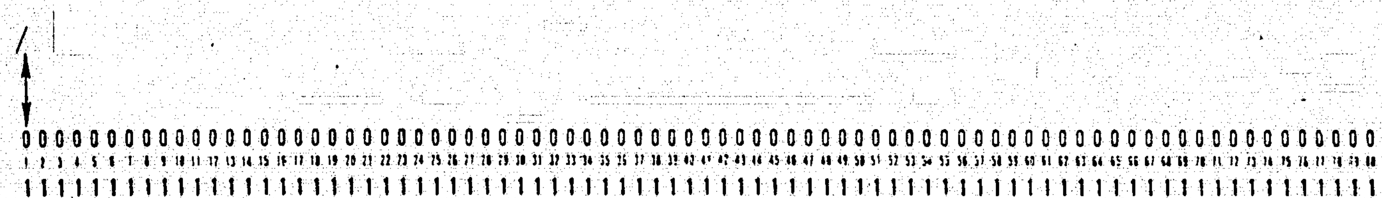
N = 2 indicates IFIXED common

LLLL is the cell number in the common block

....XXXXX is ten columns of data (integers must be right justified) to be stored in cell

MM.....MM is a sixty column alphanumeric message field.

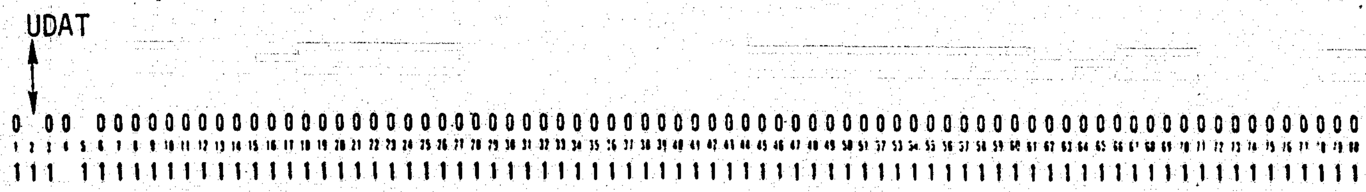
The end of this command set is signified by a card of the form:



As each of the data cards is read, the value of the particular parameter is inserted and the data and message are printed on the line printer.

User Data Input

This command set consists of a card of the form:



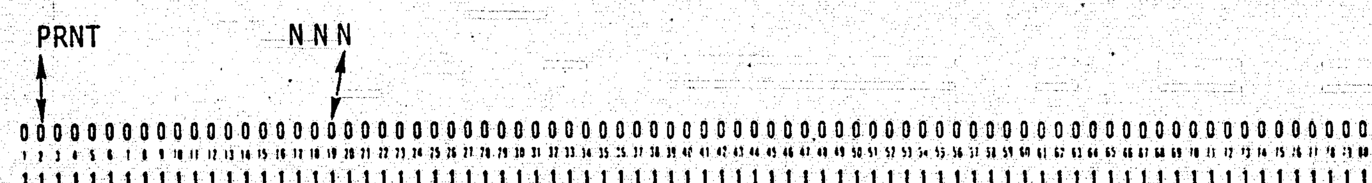
This command causes a call to the routine UDATA for input. Control is returned to DRIVER which reads the next command card.

As in DATA command, the input format is the same:

N = 1 IB common
N = 2 BT common C-8
N = 3 STL common 1819A

User Data Output

This command set consists of a card of the form:



This command causes a call to the routine PRINT (NNN) for output. Control is returned to DRIVER which reads the next command card.

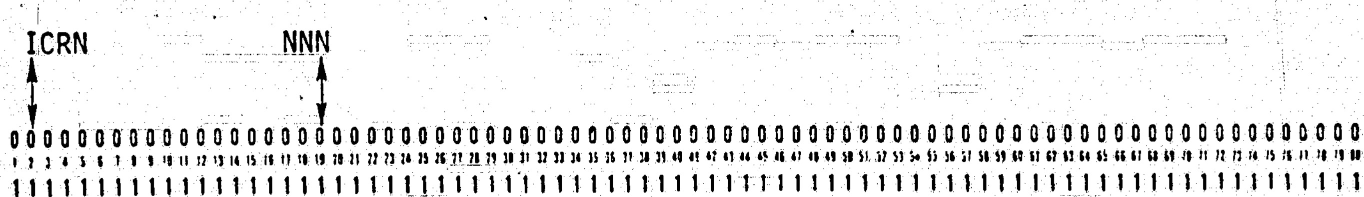
NNN = 2 Dump BASIC commons

= 3 IC Format Output

= 4 Output of 1819A variables for debugging

<u>Cycle in IC Mode</u>

This command set consists of a card of the form:

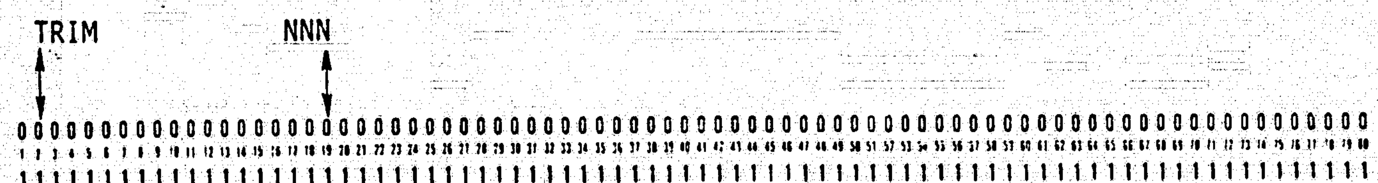


where NNN (right justified) is the number of cycles to be executed.

This command causes NNN calls to SETUP, LØØP2 and LØØP3 in a cyclic fashion with IMØDE < 0.

<u>Trim Mode</u>

This command set consists of a card of the form:

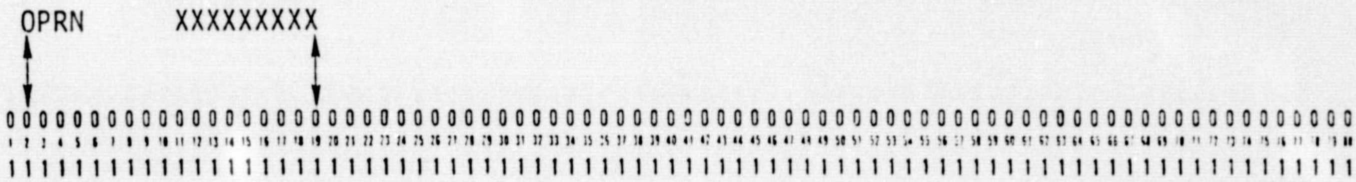


where NNN (right justified) is the maximum number of cycles the trimming process is allowed. If omitted, NNN is defaulted to 500 or the last specified value.

This command causes the trim command discrete, ITRMCN, to be set to 1 and the simulation is cycled through SETUP, LØØP2 and LØØP3 until the trim complete parameter (ITPRØG) is zero or NNN cycles have been completed.

Cycle in Operate Mode

This command set consists of a card of the form:

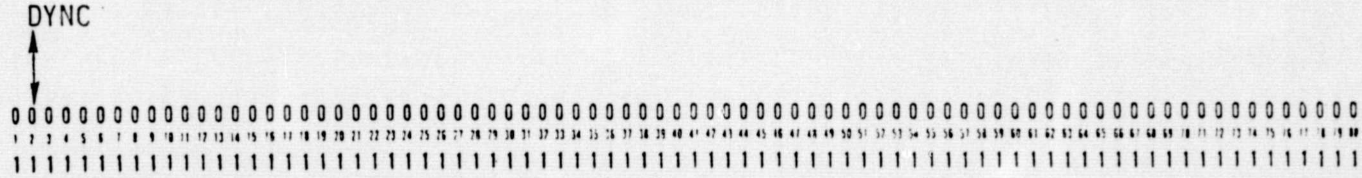


where XX...XX is nine columns of data which specify the maximum time in seconds allowed for the operate process.

This command causes the driver to perform a cyclic operation in which LØØP2 is called twice and LØØP3 is called once per cycle with IMØDE=1 until TIME $\geq$ XX...XX.

Dynamic Check Mode

This command set consists of a card of the form:



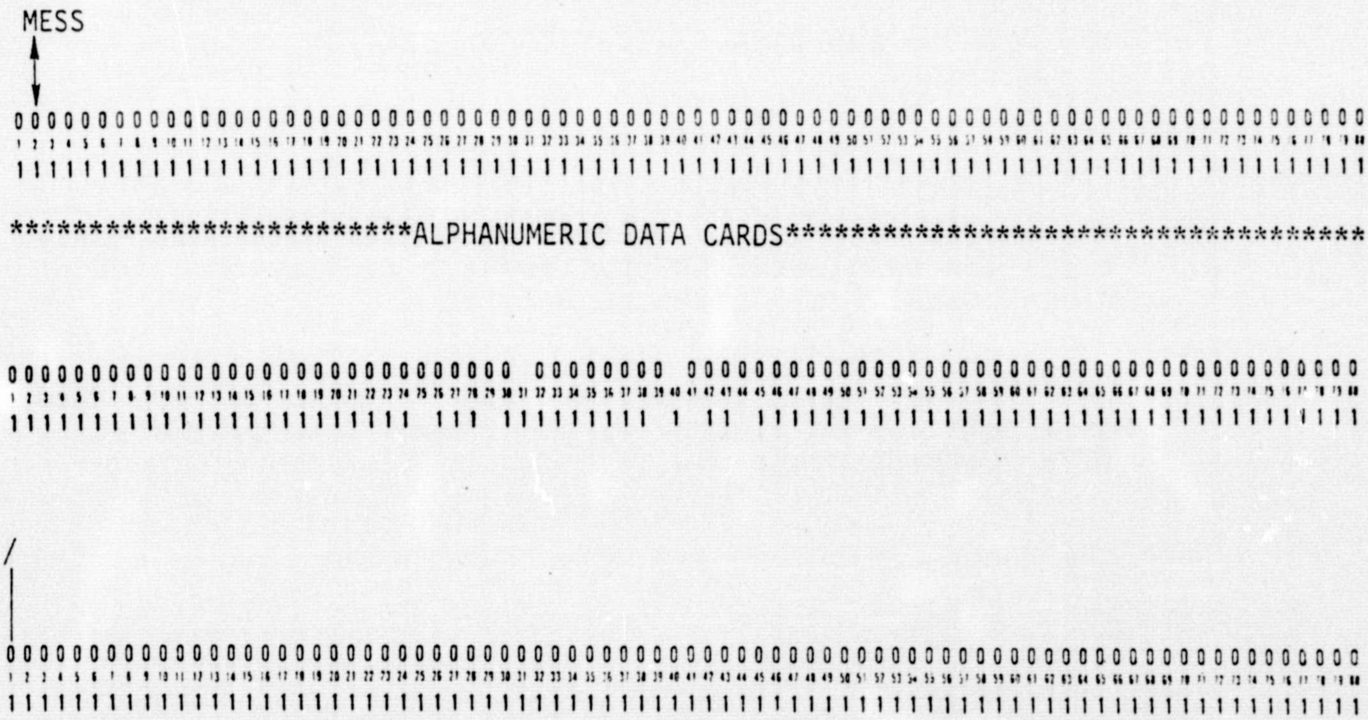
Upon receiving this command, the driver sets IDYNCH=1 and IMØDE=-1 (dynamic checks on, IC mode). The simulation is then cycled in the IC mode until the dynamic check routine (BDCHEK [3]) assumes mode control. BDCHEK maintains mode control through calls to ICRTN, HLDRTN and OPRTN (which set IMØDE), and the dynamic checks are performed.

The user must supply all pertinent data for the dynamic checks (AMVECT(I), DTD, ICØDE,...,etc.) by use of the DATA or UDAT command sets prior to invoking the DYNC command set.

Under the current driver, the user must allow for data output during a dynamic check or cyclic process in the operate mode. One possibility is to perform this output as a print statement in one of the utility routines (e.g., UTIL2).

<u>Message Output</u>

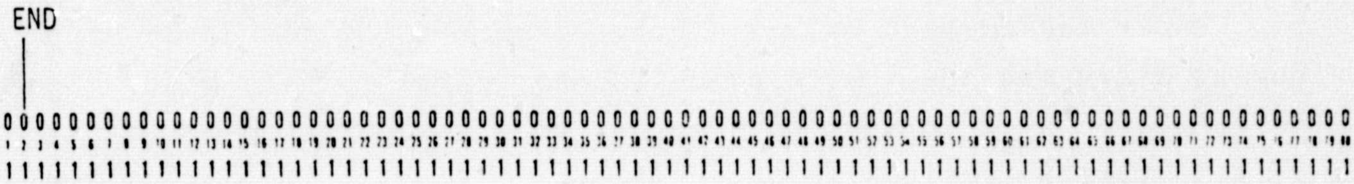
This command set consists of cards of the form:



Following the MESS command card are any number of cards with alphanumeric data in any of the 80 columns. To terminate the message, a card with a slash in column 1 is supplied. The alphanumeric data is simply output on the line printer (one line per card) without a top of form.

Terminating a Run Session

This command set consists of a card of the form:



This command notifies the driver that there are no remaining command cards. Execution is subsequently terminated by the driver.

4.5 PLOTTING OPTIONS AND DATA STATISTICS GENERATION

Output data plotting options are as follows:

(1) The output data can be written on DUMRUN tapes and these tapes can be plotted at the computer facilities. Additional details are given in Ref. 4.

(2) 360 Plots: The output can be stored in data sets when the aircraft is in the operate mode. Subsequently, these data sets can be plotted on the remote 8 terminals using ZETA plotting programs.

When the Monte Carlo runs are made, subroutine STAT is called at specified intervals. At present it is set up to compute iteratively the mean and variance of five variables; it can easily be recompiled for computing statistics of any number of variables. The program listing is given in Table 4.9.

TABLE 4.9: SUBROUTINE STAT LISTING

```
      SUBROUTINE STAT
C
C   ******************************************************************
C
C     SUBROUTINE TO COMPUTE STATISTICS FOR MONTE CARLO RUNS. IT COMPUTES
C   THE STATISTICS ( MEAN AND VARIANCE) ITERATIVEY, IT IS CALLED FROM
C   SUBROUTINE INPUT EVERY IL CYCLE OF SIMULATION.
C
C   ******************************************************************
C
      COMMON /STL/IA(1400)
      COMMON /XFLOAT/A(500)/IFIXED/IF(200)
      COMMON /ITYPE/IH(20)/HTYPE/HT(100)
C
C
      DIMENSION S(5,2,100),IZN(6),TMP(5)
C
      EQUIVALENCE ( XR,A(174)   ), (YR, A(175)  ), (HR,A(176) )
     1, (IZN(1),IA(632)   ), (IEPSY , IA(91)    ),  (IHERRG,  IA(148)   )
     2, (IVCERR, IA(357)   ), (IPHCOM,IA(228)    ),  (N      , IA(1298)  )
     3, (K      ,IA(1299)  ), (IEPSZ,IA(94)   ), (IGDLTS,IA(124)     )
C
C
      DATA  IM/5/
C
C     TABLE,DESCRIPTION:
C
C       S(J,I,K)
C                    I= 1  MEAN
C                    I= 2  VARIANCE
C
C                    J= 1  ALONG TRACK  ERROR
C                       2  CROSS TRACK  ERROR
C                       3  ALTITUDE ERROR
C                       4  AIRSPEED ERROR
C                       5  AIRSPEED ERROR RATE
C
C
C                    K  TIME INSTANT WHEN  STATISTICS ARE COMPUTED  FOR
C                       EACH RUN.
C
C
C       TMP(I)      CURRENT STATE
C
C
```

TABLE 4.9 (CONTINUED): SUBROUTINE STAT LISTING

```
C
C      N            ITERATION NUMBER FLIGHT BEING REPEATED.
C
C
       TMP(1)    = IGOLTS
       TMP(2)    =  IERSY
       TMP(3)    =  IERSZ
       TMP(4)    =  IVCERR
       TMP(5)    =  IPHCOM
C
C     FIND MEAN
C
       DO 10 I=1,IM
       S(I,1,K) = ( (N-1)*S(I,1,K)    + TMP(I)      )/N
   10  CONTINUE
C
       IF(N.EQ.1) GO TO 30
C
C     FIND VARIANCE
C
       DO 20 I=1,IM
       S(I,2,K) = (N-2)*S(I,2,K)
       S(I,2,K)=(S(I,2,K) +  (S(I,1,K)-TMP(I)  )*(S(I,1,K)-TMP(I)))/(N-1)
   20  CONTINUE
C
C      STORE  IN DAT SET
C
C
  30   K = K+ 1
 100   RETURN
       END
```

V. VALIDATION OF SHARP

As noted in Chapter I, one of the principal uses of the SHARP simulation is to perform comparative studies of navigation, guidance and control concepts for STOL aircraft. To assure the value of these Monte Carlo type simulation results, it is necessary to verify the equivalence of the SHARP and STOLAND simulations. The validation procedure and results are given in Section 5.1; the validation data shows that the two simulations are essentially identical. Section 5.2 discusses some of the differences and the main errors discovered in the STOLAND simulation during the process of SHARP program development and debugging. Section 5.3 documents some of the flight control laws in unscaled form. The work done under this effort is summarized in Section 5.4.

5.1 VALIDATION PROCEDURE AND RESULTS

The sequence of steps to validate the SHARP simulation with respect to the STOLAND simulation is outlined in this section. The autopilot modes, namely:

(1) Heading Hold,
(2) Altitude Hold,
(3) Flight Path Angle (FPA) Hold, and
(4) Go Around

were debugged by checking the parameters in the printed output after every run.

The glideslope tracking mode was debugged by checking the glideslope error. The full auto mode (4D guidance mode) was debugged by checking that the aircraft was tracking the trajectory in the straight section, turning section, and glide scope section, and

then switching to the glideslope track mode after reaching the last waypoint. The IBM 360 simulation outputs for glideslope tracking, full auto mode and flare were compared with the 1819A output of the real time simulation (STOLAND).

From the output of the IBM 360 simulation and the 1819A output listed in Tables 5.1 through 5.4, it can be seen that they agree very closely except for the flare and touchdown location. This difference can be explained by the fact that in the real time simulation there are transmission delays in commands from the 1819A to the C-8 model on the 8400 and in responses from the aircraft model to the 1819A. In the IBM 360 version, events take place instantaneously. These delays could be incorporated into the IBM 360 version, but it is very difficult to estimate them.

The transmission delay and its effects were first noticed when the auto-throttle loop, which was being closed on the 8400, was closed on the 1819A. As there is no transmission delay in the IBM 360 simulation, by comparing the errors (BETAGS) in the output of the slideslope tracking mode in Table 5.1, it can be seen that there is much tighter control in the 360 version of the simulation.

5.2 SIMULATION DIFFERENCES

The aspects in which the SHARP and the STOLAND real time simulations differ are described below:

(1) The simulation on the IBM 360 (SHARP) has been implemented only for the full auto flight mode (i.e., there are no manual or flight director modes). The structure of the simulation is exactly like the real time simulations, so other modes can be easily added. If the full auto mode is not turned on, the simulation can be run in modes like heading hold, FPA hold, altitude hold, etc.

(2) The switches and buttons on the control panel in the cockpit have been replaced with corresponding discrete flags. These are described in Appendix B.

TABLE 5.1: GLIDESLOPE; STOLAND WIND (VARYING WITH ALTITUDE); NO NAVIGATION BIAS

	SHARP (IBM 360) OUTPUT				STOLAND OUTPUT		
	IBTAGS 360*DEG	IZN(2) FT./4	IZN(4) FT./4	IZN(6) 4*FT.	BETAGS 360*DEG	ZN(2) FT./4	ZN(6) 4*FT.
	3	-1430	-3	-2445	2	-1437	-2459
2	5	-1378	-2	-2357	2	-1387	-2374
4	7	-1326	-2	-2268	2	-1336	-2289
6	8	-1274	-3	-2181	1	-1285	2204
8	9	-1223	-4	-2094	- 1	-1234	-2120
10	9	-1172	-4	-2007	- 3	-1183	-2036
12	9	-1121	-4	-1921	- 6	-1131	-1953
14	9	-1070	-3	-1831	- 8	-1081	-1868
16	8	-1019	-2	-1749	- 12	-1029	-1784
18	8	-968	-1	-1664	- 15	- 978	-1701
20	8	-916	-1	-1578	- 19	- 927	-1617
22	8	-865	-1	-1491	- 23	- 875	-1532
24	8	-813	-1	-1405	- 27	- 823	-1446
26	7	-762	-1	-1318	- 31	- 772	-1360
28	7	-710	-1	-2132	- 34	- 720	-1274
30	8	-658	0	-1145	- 35	- 668	-1166
32	9	-607	0	-1058	- 36	- 616	-1098
35	10	-555	0	- 971	- 36	- 565	-1009
36	10	-503	0	- 884	- 35	- 513	- 921
38	12	-451	0	- 797	- 32	- 461	- 831
40	14	-399	0	- 710	- 29	- 409	- 742
42	17	-348	0	- 622	- 23	- 358	- 652
44	22	-296	0	- 534	- 14	- 306	- 562
46	27	-243	0	- 446	- 1	- 254	- 472
48	36	-191	0	- 358	18	- 202	- 381
50	55	-138	0	- 269	50	- 150	- 291
52	108	-85	1	- 179	+111	- 98	- 200
	FLARE				FLARE		

TABLE 5.2: FLARE STOLAND WIND; NO NAVIGATION BIAS

SHARP (IBM) OUTPUT				STOLAND (1819A) OUTPUT		
TIME	IZN(2)	IZN(6)	IPSIA	ZN(2)	ZN(6)	PSIA
	-67	-148	-1103	-72	-155	1064
1.0	-54	-125	-1128			
	-40	-105	-1210	-46	-110	-1143
2.0	-27	- 89	-1822			
	-14	- 77	-2203	-20	- 78	-1809
3.0	- 1	- 69	-2219			
	13	- 63	-2401	6	- 61	-2298
4.0	24	- 58	-2524			
	37	- 54	-2516	31	- 52	-2529
5.0	49	- 51	-2561			
	61	- 58	-2608	54	- 44	-2588
6.0	73	- 44	-2602			
	85	- 41	-2606	60	- 42	-2574
	TOUCHDOWN			TOUCHDOWN		

TABLE 5.3: FLARE WITH STOLAND WIND AND MLS BIAS

	SHARP (IBM 360) OUTPUT		STOLAND (1819A) OUTPUT
TIME	ELEV. DEFL. (DE)	ELEV. COM. (IDELCS)	ELEV. COM. (DELECS)
	-1.25	7	-1
0.2	-3.22	64	97
	-7.95	135	165
	-8.40	142	162
	-7.22	122	116
1.0	-5.42	89	68
	-4.69	72	40
	-4.35	64	43
	-4.29	61	49
	-4.63	64	54
2.0	-4.69	65	59
	-4.58	62	57
	-4.75	65	54
	-4.58	62	48
	-4.64	64	44
3.0	-4.47	62	43
	-4.69	64	46
	-4.64	64	49
	-4.70	65	48
	-4.76	67	50
4.0	-4.70	65	54
	-4.87	69	57
	-4.88	70	60
	-4.88	70	61
5.0	-4.49	73	62
	-5.17	75	65
	-5.34	78	68
	-5.29	78	70
	-5.29	79	77
6.0	-5.58	84	
	-5.87	89	TOUCHDOWN
	-6.28	94	
	-6.28	96	
	-6.75	102	
TOUCHDOWN			

TABLE 5.4.- FLARE WITH STOLAND WIND AND NAVIGATION BIAS

	SHARP (IBM 360) OUTPUT					STOLAND (1819A) OUTPUT				
TIME	IHDTCM	ITHCOM	IZDDRA	IZN(5)	IZN(6)	HDOTCM	THTCOM	ZDDRA	ZN(5)	ZN(6)
	-3802			4402	-169	-3768	115	-14	4477	-170
	-3392	543	106	4407	-160	-3362	609	26	4480	-160
	-3025	1051	161	4438	-151	-2999	1233	253	4510	-151
	-2698	1217	-238	4462	-142	-2674	1559	50	4557	-142
	-2406	1130	-841	4465	-133	-2386	1497	-577	4536	-132
1.0	-2146	949	-1343	4228	-124	-2128	1194	-1295	4376	-123
	-1913	768	-1644	3956	-116	-1898	850	-1806	4081	-114
	-1705	634	-1742	3631	-108	-1692	651	-1930	3711	-106
	-1520	551	-1687	3287	-101	-1508	536	-1863	3330	-99
	-1354	482	-1580	2951	-94	-1344	477	-1706	2972	-92
2.0	-1208	407	-1473	2636	-89	-1198	450	-1512	2646	-86
	-1077	331	-1366	2342	-84	-1068	422	-1342	2357	-81
	-959	297	-1205	2072	-79	-951	381	-1208	2097	-77
	-854	270	-1047	1829	-75	-847	320	-1111	1860	-73
	-761	220	-944	1616	-72	-754	274	-1004	1647	-69
3.0	-677	181	-841	1426	-69	-671	229	-910	1457	-66
	-603	187	-685	1259	-67	-597	247	-740	1290	-63
	-537	179	-578	1120	-64	-531	258	-610	1153	-60
	-477	185	-472	1003	-62	-472	261	-517	1041	-58
	-424	170	-418	908	-60	-419	289	-412	951	-56
4.0	-377	193	-313	823	-59	-372	320	-321	880	-54
	-335	195	-260	758	-57	-330	375	-216	828	-52
	-297	242	-156	706	-56	-293	414	-149	789	-51
	-263	266	-102	669	-55	-260	464	-81	764	-49
	-233	298	-49	643	-54	-230	497	-54	751	-47
5.0	-206	340	4	629	-52	-203	550	-13	749	-46
	-182	356	6	625	-51	-179	597	15	752	-44
	-161	372	7	624	-50	-158	642	42	756	-43
	-141	423	60	623	-49	-138	718	108	764	-41
	-125	481	113	631	-48	TOUCHDOWN				
6.0	-109	517	114	650	-47					
	-96	595	167	676	-45					
	-84	645	168	709	-44					
	-72	737	220	746	-43					
	-63	802	221	790	-41					
	TOUCHDOWN									

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(3) There are transmission delays between command initiation in the Sperry 1819A and the corresponding response from the C-8 model in the EAI-8400; in the IBM 360 simulation, events take place instantly. The delays could be incorporated in the IBM 360 version, but it is difficult to obtain reliable estimates of these delays.

(4) Instead of modeling the pressure transducer as in the real time simulation, calibrated dynamic pressure, true air speeds, and baro-altitude are taken directly from the BASIC program on the IBM 360. If desired, a constant bias can be added to the baro-altitude.

(5) Because the IBM 360 version is completely duplicatable, simulation runs with the same initial conditions will give the same results. In the real time simulation, setting up the initial conditions is very inconvenient, and results from run-to-run are not exactly alike.

5.3 FLIGHT CONTROL LAWS

As noted earlier, the SHARP and STOLAND simulations are essentially identical. For example, the control laws used in both simulations are exactly the same in structure and have the same scale factors. In the interest of comparing these STOLAND control laws with those used by other flight control systems, unscaled versions of the pitch axis control laws and the auto-throttle system are described in this section. Figure 5.1 shows the longitudinal control system; the corresponding glideslope tracking law is shown in Fig. 5.2. The auto-throttle speed control law is presented in Fig. 5.3 and the corresponding auto-throttle servo loop is shown in Fig. 5.4. The principal reason for presenting these control laws in unscaled form is to facilitate comparison with other airborne flight control systems.

Errors discovered and corrected include the following:

(1) When the navigation package in the 360 version was being debugged, it was discovered that the MLS azimuth valid discrete was incorrectly set to "not valid" as the air-

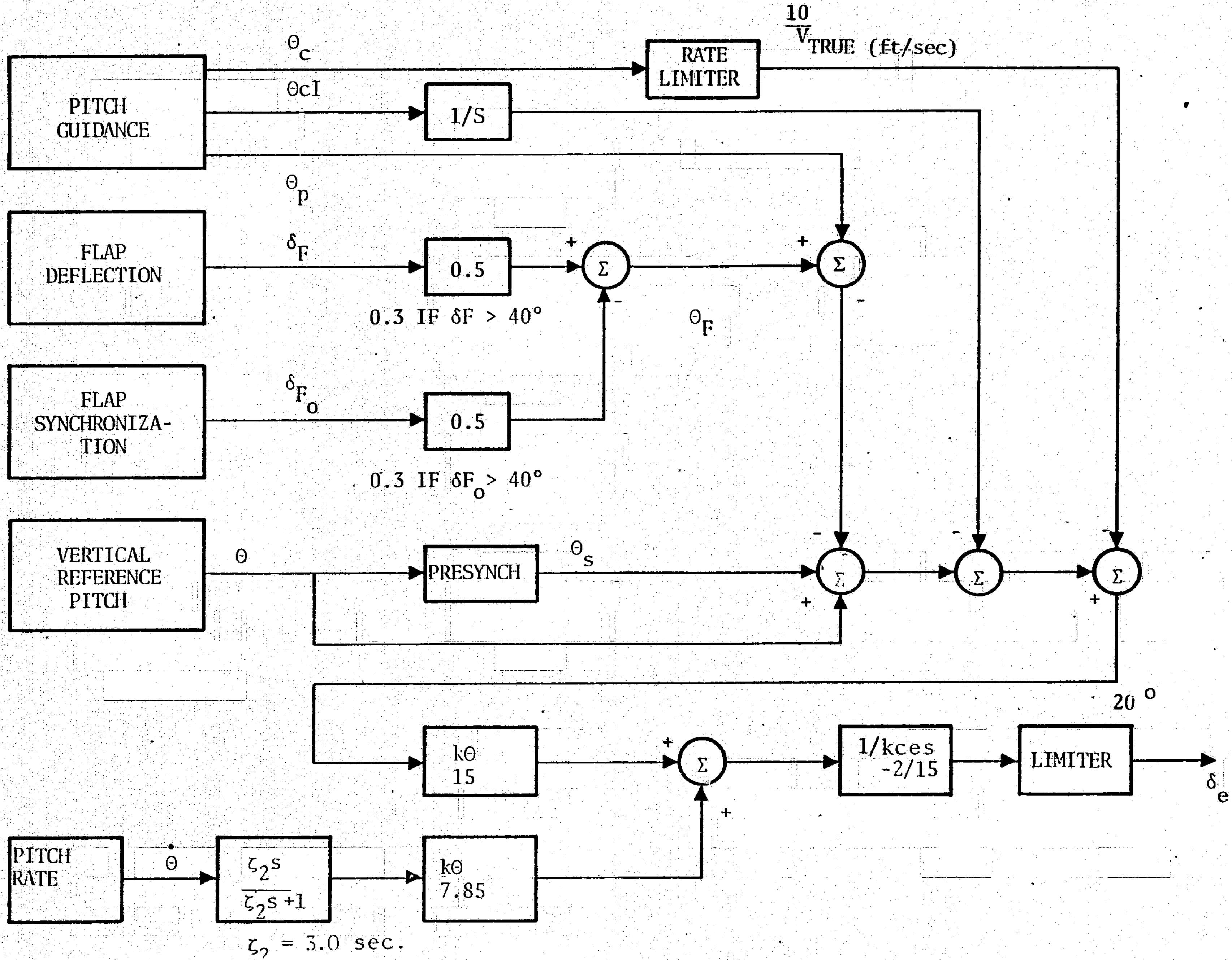

FIGURE 5.1.- LONGITUDINAL CONTROL SYSTEM

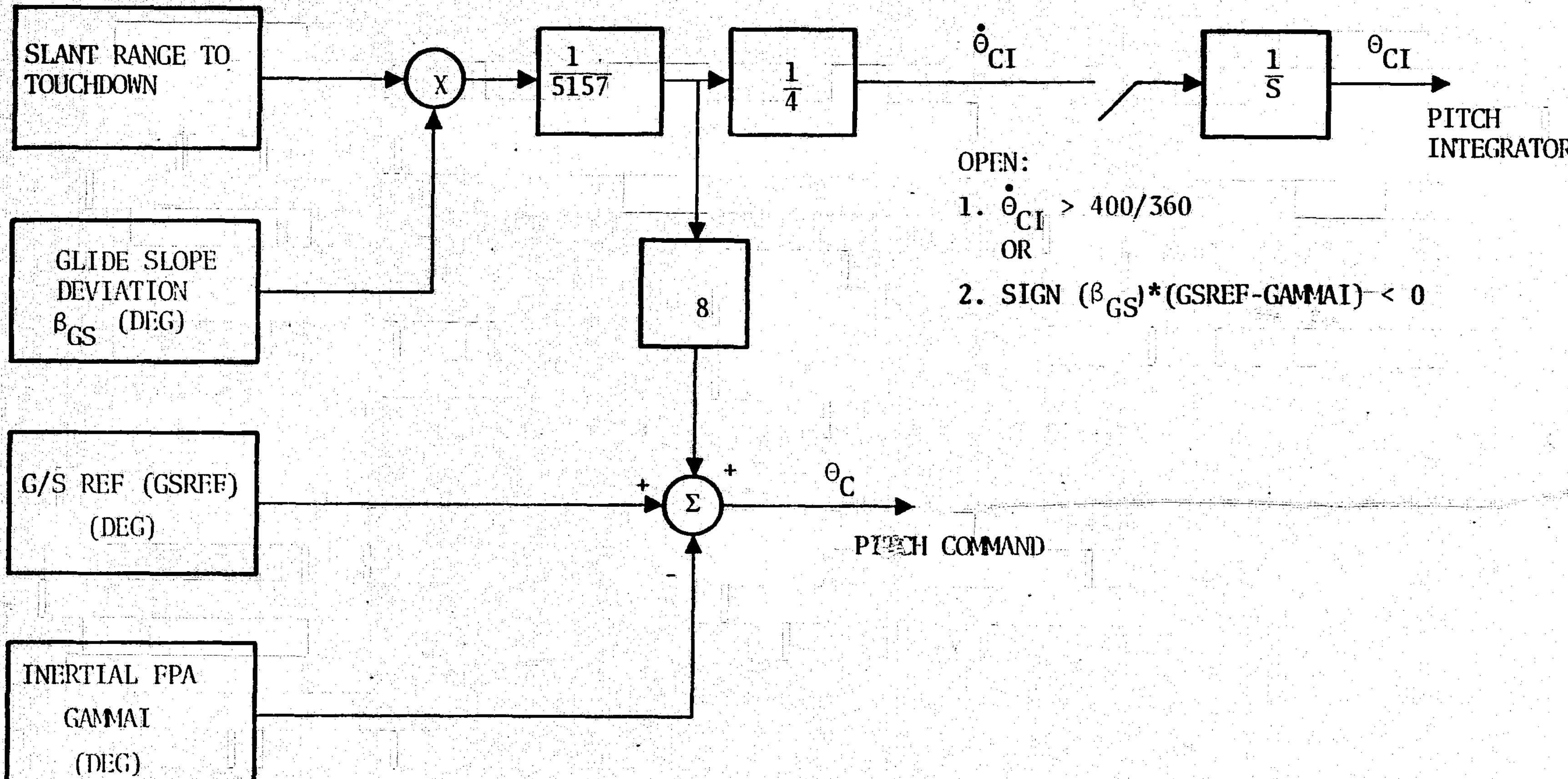

FIGURE 5.2.- GLIDESLOPE TRACK CONTROL LAW

1 Closed When

(1) $|V'_c| < 8.1$

OR

(2) $(\ddot{X} < 0)$. AND. (VCERR > 0)

OR

(3) $(\ddot{X} > 0)$. AND. (VCERR < 0)

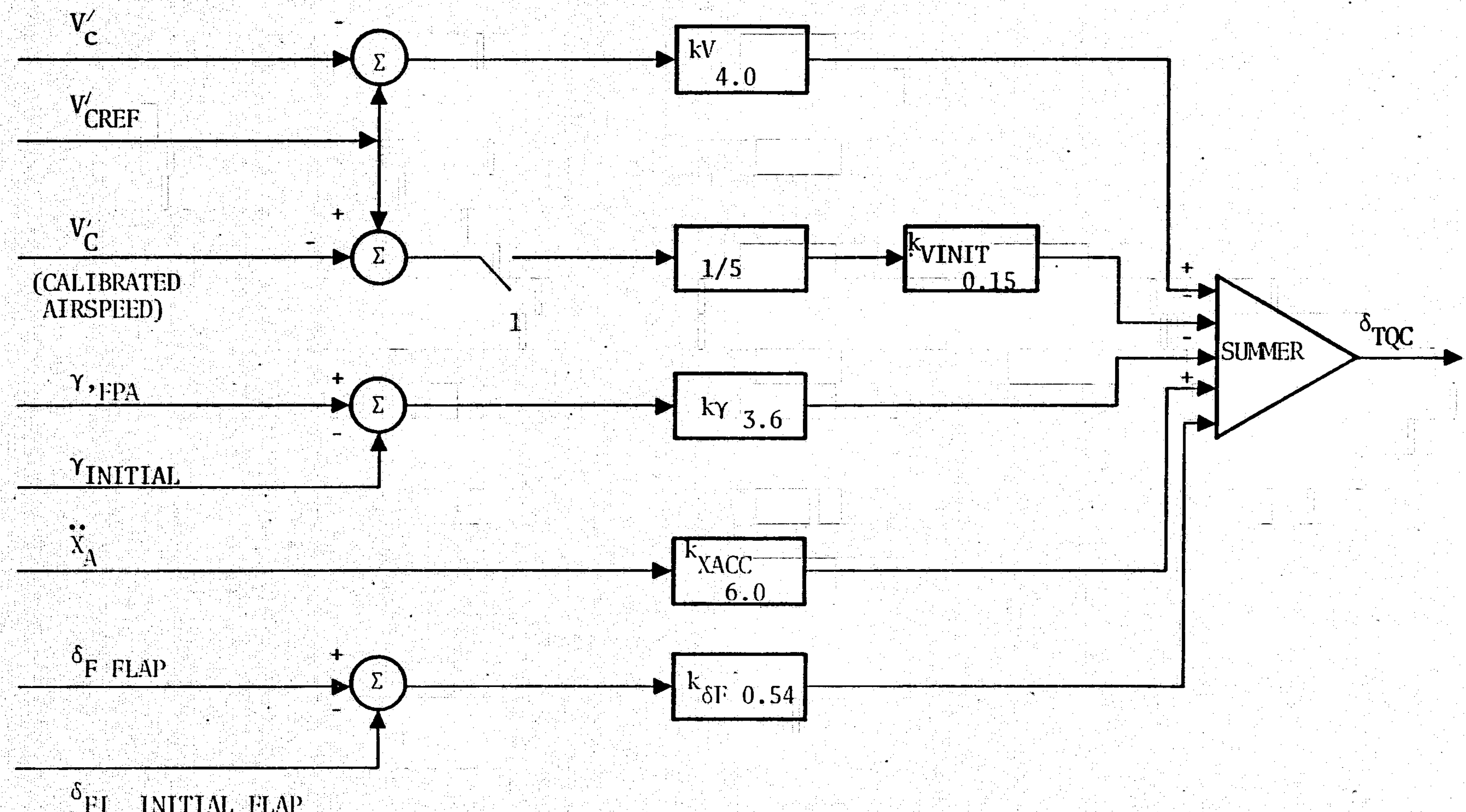

FIGURE 5.3.- AUTOTHROTTLE SPEED CONTROL LAW

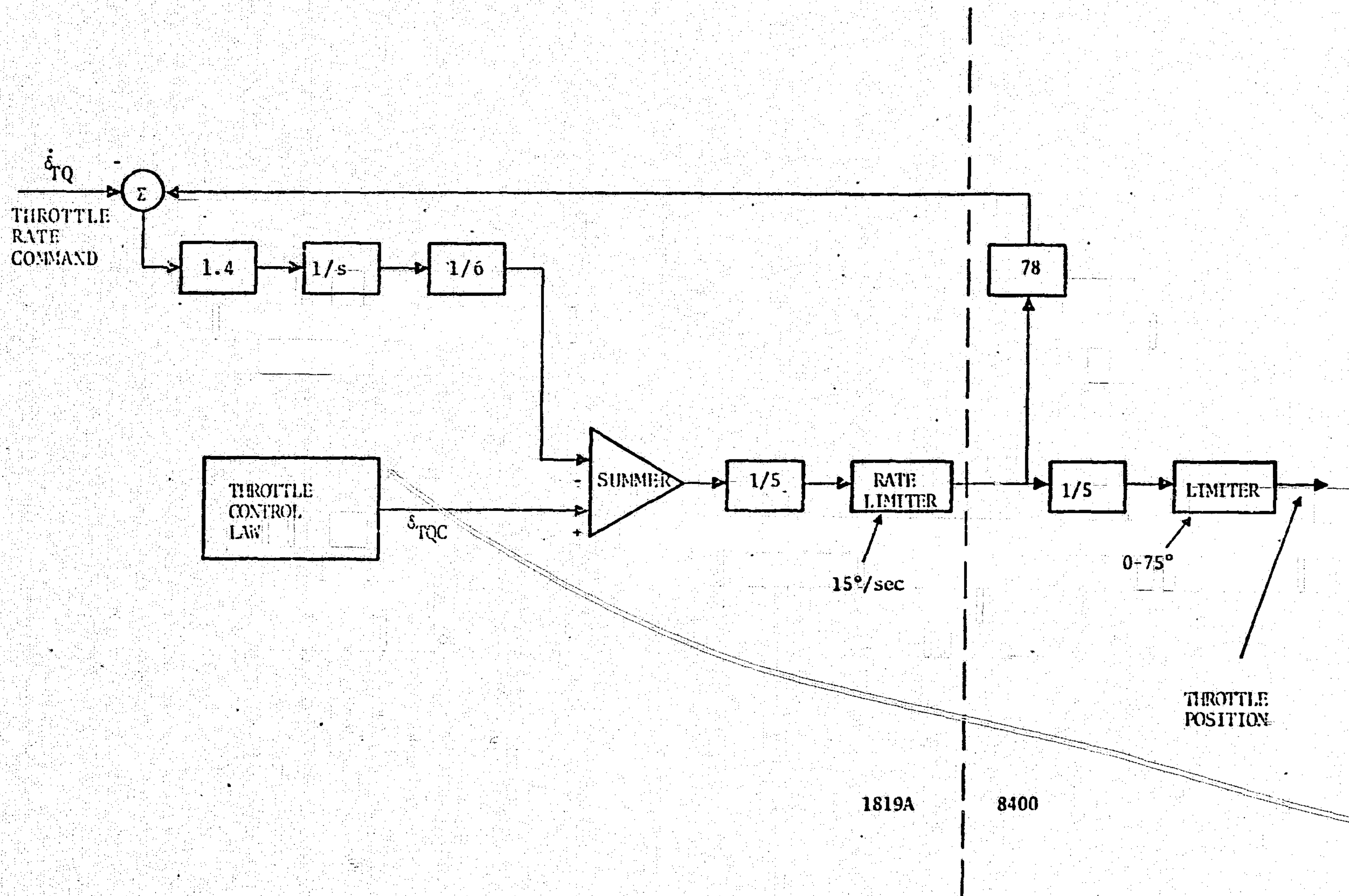

FIGURE 5.4.- AUTOTHROTTLE SERVO LOOP

craft passed over the first elevation antenna; this was corrected in both the real time simulation and the 360 simulation.

(2) The TACAN antenna locations on the EAI-8400 side and on the 1819A are not exactly the same; these have been corrected on the 360 version, but apparently small differences do not create large navigation errors in the real time simulation.

(3) In the SBLGSN subroutine during the computations of runway coordinates from MLS navigation signals, the factor C was scaled down by 2^{-15} and the term $\sqrt{B^2-AC}$ by 2^{-6} in the equation

$$X_R = \frac{B-\sqrt{B^2-AC}}{A}$$

In the 360 version, the computations were changed from fixed point arithmetic to floating point arithmetic. SBLGSN routine has been rewritten in the real time simulation.

(4) In the real time version, flaps, which are supposed to automatically adjust, are held fixed during the flight, and flap deflection contribution to the pitch command is set to zero. In the 360 version, the flaps are also held fixed. The existing FLAPS subroutine in the 1819A is quite complex and it has been duplicated in the 360 version.

(5) The interface in the 360 version, between the C-8 model and the control programs, had a number of bugs (e.g., the course was being transferred instead of the yaw angle) and many scale factors were incorrect; all these have been corrected.

(6) Initially, parts of function tables used in the ENGINE subroutine of the C-8 model were missing. Consequently, the aircraft was developing asymmetric thrust. The function tables were recompiled.

(7) When the real time simulation was running in the full auto (4D guidance) mode, it was noted from the 1819A printout that while switching modes near the last waypoint, the 1819A goes into the manual mode (CWS) for a few seconds. In the IBM 360 simulation, there is no manual mode and, thus, no such switching occurs.

(8) Finding the bugs in the original 1819A program was a very time-consuming process, as first the possibility of errors

in conversion from 1819A code to FORTRAN had to be checked. Some bugs, such as assembly errors in the DECRAB routine, were particularly difficult to correct.

(9) The BASIC package is supposed to have a provision for stopping the simulation or setting a flag called IHIT as soon as the aircraft has touched down, but in the current version of BASIC on the 360, IHIT is not being set in the manner desired. Consequently, another parameter has been added on the 1819A side; this is the altitude in bits (-4* ft), below which the operate mode is terminated.

5.4 PROCEDURAL DIFFERENCES

The main features of the STOLAND routines converted to SHARP and the associated operating procedural details are summarized in this section:

(1) Interface Definition and Programming: In the real time simulation, the airborne hardware simulator links the 1819A and 8400 computers, but in the 360 version of the simulation, a very simple interface was defined between the 1819A program and the aircraft model. The interface consists of scaling the quantities as they are passed from one side to another. Scaling is necessary as the 1819A uses integer arithmetic and most of the variables are scaled to increase accuracy.

(2) Mode Interlock Executive: Commands for switching to different autopilot modes such as flight path angle hold, altitude hold, etc., are entered via buttons which are part of the real time simulation hardware. On the 360, the mode interlock executive was programmed so that it checks for ON/OFF flags corresponding to different modes. The subroutines for all the modes have been programmed on the 360.

(3) Auto-Pilot: Only the full auto version of the auto-pilot has been programmed on the 360. Manual inputs such as control wheel steering and stick force and their associated logic and control portions have been removed. All the auto-pilot modes that are involved in full auto flight have been programmed and debugged. Certain auto pilot modes such as altitude hold, FPA hold, heading hold, and go around, which are not used in full auto flight, have also been debugged.

(4) 4D Guidance: In the 1819A program, 4D guidance computations were done parasitically over a few 50 millisecond cycles. In the 360 version, the 4D computations are done in one cycle. The 4D guidance executive and all its subroutines have been converted to FORTRAN in the 360 simulation. These subroutines have been debugged.

(5) Navigation: The navigation executive in the 1819A and most of its subroutines have been converted to FORTRAN. MLS and TACAN signal generation subroutines on the 8400 side have been converted and debugged. The MLS navigation routines on the 1819A side have also been debugged. The complementary filters for navigation in the 1819A have been checked out. The switch-over from TACAN to MLS as the C-8 enters the MLS coverage region has been checked.

(6) Monte Carlo Capability: A looping capability has been added to the simulation so that Monte Carlo runs can be made.

VI. SUMMARY

This report documents the purpose, capabilities, implementation, operating details and validation of the SHARP program. The purpose of this program is to allow Ames Researchers to conduct realistic research and development projects in the area of STOL transport aircraft. More specifically the principal use of this simulation package on the IBM 360 are to perform Monte Carlo type system studies and development of novel avionics software for the STOLAND system in an efficient manner.

This avionics research package is capable of simulating in accurate detail the entire STOLAND hardware/software system, in the fully automatic flight control mode. The implementation details of this package are described in this report. A key feature of this implementation is that the fixed point arithmetic/logical operations performed by the Sperry Avionics Computer (1819A) are duplicated on the IBM 360. This enables essentially equivalent STOLAND and SHARP simulation results.

This report also documents the operating details, including deck setups. The operating procedures are illustrated by several examples for different portions of a typical flight profile. The validation procedure and results are documented in this report to demonstrate the equivalence of the STOLAND and SHARP simulation results. Moreover key simulators and procedural differences between the two simulations are identified and discussed. Current and proposed research projects using this simulator on the IBM 360 continue to demonstrate the value of this program to AMES research personnel.

APPENDIX A

AIRCRAFT DEPENDENT PARAMETERS

Some simulation studies require the alteration of aircraft characteristics. A partial list of aircraft dependent parameters in the basic floating point common area are listed, to facilitate the conversion process.

BASIC FLOATING POINT COMMON

Com. Alloc. No.	Name	Description	Units
180	AREA	Wing area	ft
256	CG	Center of gravity	parts
295	CG DELT	C.G. modification	parts
294	CG ZER	Basic C.G. position without modification	parts
182	CHORD	Mean aerodynamic chord	ft
370	DELAT	Delta ambient temperature	degree C
321	GDTIM	Landing gear down transit time	sec
320	GUTIM	Landing gear up transit time	sec
181	SPAN	Wing span	ft
177	WAIT	Aircraft gross weight	lbs
242	WAIT1 C	Initial gross weight of aircraft	lbs
199	XIE	X-position of inner engine W/R/T C.G.	ft
116	XIXX	Vehicle X-moment of inertia	slug-ft
243	XIXXIC	Initial X moment of inertia	slug-ft
119	XIXZ	Vehicle XZ-moment of inertia	slug-ft
246	XIXZIC	Initial XZ moment of inertia	slug-ft
117	XIYY	Vehicle Y-moment of inertia	slug-ft
244	XIYYIC	Initial Y moment of inertia	slug-ft
118	XIZZ	Vehicle Z-moment of inertia	slug-ft
245	XIZZIC	Initial Z moment of inertia	slug-ft
193	XLG	X-position of left wheel WRT C.G.	ft
187	XNG	X-position of nose wheel W/R/T C.G.	ft
196	XOE	X-position of outer engine W/R/T C.G.	ft
171	XP	X position of pilot with respect to C.G.	ft

BASIC FLOATING POINT COMMON (cont'd)

Com. Alloc. No.	Name	Description	Units
190	XRG	X-position of right wheel W/R/T C.G.	ft
184	XTAIL	X-position of tail point W/R/T C.G.	ft
200	YIE	Y-position of inner engine (right)	ft
188	YNG	Y-position of nose wheel W/R/T C.G.	ft
197	YOE	Y-position of outer engine (right)	ft
172	YP	Y-position of pilot with respect to C.G.	ft
191	YRG	Y-position of right wheel W/R/T C.G.	ft
198	ZOE	Z-position of outer engine	ft
173	ZP	Z position of pilot with respect to C.G.	ft
192	ZRG	Z-position of right wheel W/R/T C.G.	ft
185	ZTAIL	Z-position of tail point W/R/T C.G.	ft
201	ZIE	Z-position of inner engine	ft
195	ZLG	Z-position of left wheel W/R/T C.G.	ft
189	ZNG	Z-position of nose wheel W/R/T C.G.	ft

APPENDIX B:

AIRCRAFT/AVIONICS INTERFACE DETAILS

The appendix tabulates the interface details of the C-8A aircraft simulation and the SHARP avionics simulation. These include parameter lists and scale factors for parameters which are transferred, (1) from the aircraft simulation to the avionics simulation (2) from the avionics simulation to the aircraft simulation (3) the interface common block and (4) the STOLAND (STL) avionics common block. The purpose of these scale factor and block lists is to facilitate the useage, modification and understanding of the SHARP program.

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B-1: SUBROUTINE UTIL2:

Parameters Transferred from A/C Model (8400) to 1819A:

Variable	STL Common Cell	Description	Scale Factor	Dimension (before scaling)
IACCXB	1	Body axis accel. x-component	1000/g	ft/sec^2
IACCYB	2	Body axis accel. y-component	1000/g	ft/sec^2
IACCZB	3	Body axis accel. z-component	1000/4g	ft/sec^2
ITHETA	323	Pitch angle (Euler angle)	360	degrees
IPSI	233	Yaw angle (Euler angle)	360	degrees
IPHI	1249	Roll angle (Euler angle)	360	degrees
IDLFLP	58	Flap deflection	900	degrees
ITHRTE	327	Throttle rate	73.431	deg/sec
ITHDOT	321	Pitch rate	20626.5 (360xdeg/rad)	rad/sec
IPHDOT	232	Roll rate	20626.5 (360xdeg/rad)	rad/sec
IPSDOT	245	Yaw rate	20626.5 (360xdeg/rad)	rad/sec
IPSIA	247	Aircraft heading (yaw angle)	360	degrees
IZCG	1246	Sea altitude (bak° altitude)	4	ft
IYCG	1248	Y coordinate of center of gravity	1/4	ft
IHCG	1265	Height (of A/C) above runway	4	ft
IXCG	1247	X coordinate of center of gravity	1/4	ft
IRNALT	1261	Runway altitude	4	ft

B-1: SUBROUTINE UTIL2: (Cont'd)

Parameters Transferred from A/C Model (8400) to 1819A:

Variable	STL Common Cell	Description	Scale Factor	Dimension (before scaling)
IDS45	77	Throttle not minimum	discrete	
IDS23	79	Flaps engaged	discrete	
IDS411	435	Throttle not maximum	discrete	
IMODE	1300	IC (<0)/operate (>0)	discrete	

Parameters Transferred from 1819A to A/C Model (8400):

Variable	STL Common Cell	Description	Scale Factor	Dimension (after scaling)
IDELCS	47	Elevator command	0.01654	degrees
IDLACS	55	Roll command	0.04893	degrees
IDLRCS	60	Yaw command	0.01728	degrees
IDLTQC	62	Throttle rate command	0.04	deg/sec

Other Parameters Transferred from A/C Model to 1819A Package:

1. Navigation discretes set in a) NAVMLS
   b) VORTC

   See navigation parameter list in STL common block (Section B.3)

2. Calibrated and true airspeeds and barometric pressure picked up in the input subroutine.

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
BTYPE/BT(50)					
BT(001)	C_{1p}	CLP		N.D.	AERO2
BT(002)	C_{np}	CNP		N.D.	AERO2
BT(003)	$C_{m\alpha}$	CMALPD		N.D.	AERO2
BT(004)	$\partial C_e/\partial W$	DLCLDW		N.D.	AERO2
BT(005)	$SC_L(C_T,\alpha,S_f)$	DELCL		N.D.	AERO3
BT(006)	$Ltail/\bar{c}$	LTOVC		N.D.	AERO2
BT(007)	$C_T=C_{T_1}+C_{T_2}$	CT		N.D.	AERO2
BT(008)	$C_{T_1}=7HP/QS$	CT1		N.D.	AERO2
BT(009)	$C_{T_2}=THS/GS$	CT2		N.D.	AERO2
BT(010)	Th_p	THP	Port Engine Thrust	LB	ENGINE
BT(011)	Ths	THS	Starboard Engine Thrust	LB	ENGINE
BT(012)	Np	RPMP	RPM of Engine, Port	rpm	ENGINE
BT(013)	Ns	RPMS	RPM of Engine, Starboard	rpm	ENGINE
BT(014)	qS	QS	$(1/2Sv^2)(S)$ for normalizing $C_C;C_L,C_X,$	LB	AERO3
			C_y, . ., etc.		
BT(015)	$\bar{C}/ZV_\infty$	COV2VA		SEC	AERO3
BT(016)	$b/2V_\infty$	BOV2VA		SEC	AERO3

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
BT(017)	$(\text{frad})^2$	DFRSQ		$(\text{rad})^2$	AERO2
BT(018)	δ_e command	THMCE	Commanded Elevator from 1819	°drum	SCALE
BT(019)	δ_a command	THMCN	Commanded Aileron from 1819	°drum	SCALE
BT(020)	δ_r command	THMCP	Commanded Rudder from 1819	°drum	SCALE
ITYPE/IB(20)					
IB(01)		ISPOIL		NA	DATA
IB(02)		IGUST		NA	DATA
IB(03)		MO	Set in Engine	NA	ENGINE
IB(04)		ITURB	Set in WINDC -0 turbulence out	NA	DATA
			-1 turbulence in		
IB(05)		ITNMIN	Throttle not min. 0-throttle≤min 1-throttle>min	NA	ENGINE
IB(06)		ITNMAX	Throttle not max. 0-throttle>max. 1-throttle≤max.	NA	ENGINE
IB(07)		IDYNPR	= 1 allows dynamic printing	NA	DATA
IB(08)		IDYNTP	= 1 allows dynamic tape write via	NA	DATA
			DUMRUN		
IB(09)		ITCLOS	= 1 causes DUMRUN tape to be closed	NA	DATA
IB(10)		IDLEBT	Blade Angle Stop Flag	NA	DATA

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
IB(11)		IFLAP	1→flap has reached commanded pos. 0→flap has not reached commanded pos.	NA	CONTR3
IB(12)		NTRY	Default = 20		SETUP
IB(13)		IWIND	2 altitude variable wind, 1 zero wind, 4 fixed wind		
IB(14)		KF	Setup		SETUP
IB(15)		KDELAY	$UTIL2_1$		UTIL2
LB(16)		ICALL	$UTIL2_1$		UTIL2
BTYPE					
BT(40)	default-1.5	DLTRML	Lower limit for DELTRIM (calling sequence for BQUIET1)	rad	DATA
BT(41)	default+1.5	DLTRMH	Upper limit for DELTRIM (calling sequence for BQUIET1)	rad	DATA
BT(42)	default 0.,	PCLPL	Lower limit for throttle (calling sequence for BQUIET1) (PCLP)	deg	DATA
BT(43)	default 75.0	PCLPH	Upper limit for throttle (calling sequence for BQUIET1)	deg	DATA
BT(44)	-10.	THTICL	Lower limit for THETIC (calling sequence for BQUIET)		DATA

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
BT(45)	+10.	THTICH	Upper limit for THETIC (calling		DATA
			sequence for BQUIET)		
BT(46)		PCLPSP	Incremental throttle setting	deg	ENGINE
BT(47)		DELWND	Wind magnitude	H/rec.	WIND
BT(48)		PSIWND	Direction (blowing to) relative to	rad	WIND
			the Mag. North		
BT(49)		VOS	Wind magnitude	ft/sec	WIND
BT(50)		AMWP	Direction (turning from) relative to	rad	WIND
			the runway		
NAVAGATION	PARAMETERS:				
BT(51)		RBLAS	MLS noise parameters	ft	NAVMLS
BT(53)		E2B1AS	MLS noise parameters	deg	NAVMLS
BT(54)		ABIAS	MLS noise parameters	deg	NAVMLS
BT(55)		VAKGRD	TACAN noise parameters		VORTC
BT(56)		DT12	TACAN noise parameters		VORTC
BT(57)		GBIAS	TACAN noise parameters		VORTC
BT(58)		OMEGAL	TACAN noise parameters		VORTC

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
BT(59)		OMEGAS	TACAN noise parameters		NORTC
BT(60)		DMBIAS	TACAN noise parameters		VORTC
BT(61)		DMEB	TACAN noise parameters		VORTC
BT(62)		SIGC	TACAN noise parameters		VORTC
ST(1350)		IABIAS	Altimeter bias	-4*feet	
STL COMMON					
ST (1282)	DISCRETE	INOIS4	= 1 TACAN bearing noise on		VORTC
ST (1289)	DISCRETE	INOIS5	= 1 TACAN range noise on		VORTC
ST (1285)	DISCRETE	NOIS1	= 1 DME noise on		NVMLS
ST (1286)	DISCRETE	NOIS2	= 1 Azimuth noise on		NVMLS
ST (1287)	DISCRETE	NOIS3	= 1 EL2 noise on	NVMLS	
ST (1288)	DISCRETE	NOIS4	= 1 EL3 noise on	NVMLS	

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
BTYPE/BT(50)					
BT(021)	δ_f command	DFC	Commanded flap position from 1819-sim	deg	SCALE
BT(022)	the rate com.	TSCRTE	Commanded throttle rate from 1819-sim	det/sec	SCALE
BT(023)	th rate	TSRATE	Throttle rate feedback for 1819-sim	deg/sec	SCALE
BT(024)	δ_e	DE	Elevator deflection + T.E. down	deg	CONTR2
BT(025)	δ_r	DR	Rudder deflection + T.E. left	deg	CONTR2
BT(026)	δ_a	DW	Aileron deflection + T.E.	deg	CONTR2
BT(027)	δ_f	DF	Flap deflection + T.E. down	deg	CONTR3
BT(028)	δ_e rad	DER		rad	CONTR2
BT(029)	δ_r rad	DRR		rad	CONTR2
BT(030)	δ_a rad	DWR		rad	CONTR2
BT(031)	δ_f rad	DFR		rad	CONTR3
BT(032)	δ_{etrim}	DELTRM	Input data or used to trim from SETUP	rad	SETUP or DATA
BT(032)	δ_{etrim} limited	DHPT	Setrim Limited from flap interconnect	rad	CONTR3
BT(033)	δ_r trim	DPTRIM	Input data and limited in CONTR3 (DRT)	rad	CONTR3
BT(034)	δ_{atrim}	DELATT	Input data and limited in CONTR3 (DWT)	rad	CONTR3
BT(035)	Power-lever	PCLP	Throttle quadrant(note: VPCLP= -PCLP +75) (for trimming or DATA INPUT)	deg	DATA

B-2: INTERFACE COMMON BLOCKS:

Common	Quantity	Fortran	Definition	Units	From
BT(036)	TORQUE	TQIP			
BT(037)	TORQUE	TQIS			
BT(038)		DFIC	Initial flap setting		
BT(039)	TURBULENCE	UDISPR			
BT(63)		RNH	MLS Random Errors		
BT(64)		ANH	MLS Random Errors		
BT(65)		E2NH	MLS Random Errors		
BT(66)		E3NH	MLS Random Errors		
BT(67)		GAMN21	TACAN Bearing Error		
BT(68)		ALPHSN	TACAN Range Error		

B-3: STOLAND AVIONICS (STL) COMMON BLOCK:

This subsection contains parameter lists and locations for, (1) discretes for initializing different modes, (2) common cells for initializing Monte Carlo runs and (3) specific label and labeled array location lists.

DISCRETES FOR INITIALIZING DIFFERENT MODES

Discrete	STL Common Cell	Subroutine	Description
ID (1)	1301	MODEIL	Mode D - standby/on mode set by program
ID (2)	1302	MODEIL	Mode1 - full auto mode
ID (3)	1303	MODEIL	Mode2 - F/D mode
ID (4)	1304	MODEIL	Mode3 - IAS hold mode (not required with auto-throttle)
ID (5)	1305	MODEIL	Mode4 - IAS select mode
ID (6)	1306	MODEIL	Mode5 - reference FP mode
ID (7)	1307	MODEIL	Mode6 - altitude hold mode
ID (8)	1308	MODEIL	Mode7 - altitude select mode
ID (9)	1309	MODEIL	Mode8 - FPA hold mode
ID (10)	1310	MODEIL	Mode9 - heading hold mode
ID (11)	1311	MODEIL	Mode10 - FPA select mode
ID (12)	1312	MODEIL	Mode11 - heading select mode
ID (13)	1313	MODEIL	Mode12 - HORNAV mode
ID (14)	1314	MODEIL	Mode113 - VOR/ILS mode
ID (15)	1315	MODEIL	Mode14 - MLS mode
ID (16)	1316	MODEIL	Mode15 - TACAN mode
IZ	1297	INPUT	When A/C descends to IZ operate is terminated. (IZ in -4 * feet). Used in Monte Carlo runs and flare.

B-3: STOLAND AVIONICS (STL) COMMON BLOCK: (cont'd)

Discrete	STL Common Cell	Subroutine	Description
IDS 01	67	MODE13	DME valid
IDS 02	68	VOR/DME	VOR valid
IDS 06	127	MODEIL	auto switch
IDS 07	69	MODEIL	SAS switch
IDS 08	1268	MODEIL	auto throttle switch
IDS 12	74	TACAN	TACAN bering not valid
IDS 13	75	TACAN	TACAN range not valid
IDS 14	1277	SBLGSN	MLS elevation valid
IDS 16	70	MODE13	VOR/LOC super
IDS 18	71	MODE13	VOR/ILS super
IDS 112	72	MODE14	SB. LOC. valid
IDS 113	436	PMLS	SB. G/S. valid
IDS 23	79	FLAPS	flap servo select
IDS 214	76	MODEIL	go around button
IDS 44	437	DISCTS	touchdown flag
IDS 45	77	TASH	throttle not min.
IDS 411	435	TASH	throttle not max.

COMMON CELLS FOR INITIALIZING FOR MONTE CARLO RUNS

IMDSWT (1,1)	1325	INPUT	mode # to be set
IMDSWT (2,1)	1326	INPUT	desired iteration # setting the mode
IMDSWT (1,2)	1327	INPUT	mode #
IMDSWT (2,2)	1328	INPUT	iteration #
IMDSWT (1,3)	1329	INPUT	mode #
IMDSWT (2,3)	1330	INPUT	iteration #
IMDSWT (1,4)	1331	INPUT	mode #
IMDSWT (2,4)	1332	INPUT	iteration #
IMDSWT (1,5)	1333	INPUT	mode #
IMDSWT (2,5)	1334	INPUT	iteration #

Present limit on iteration number is 30.

IA		IB		IC	
Name	Cell	Name	Cell	Name	Cell
IACCXB	1	IB	24	ICAPK	33
IACCYB	2	IBASE	25	ICAPKP	34
IACCZB	3	IBNM	446	ICLOK1	35
IAHICF	4	IBNM1	26	ICMPEN	36
IAILSC	5	IBRING	27	ICOSPH [ICSPHI]	37
IAL	6	IBTAGS	28		
IALT50	7	IBTAV [IBETAV]	30	ICOUNT	38
IALPMX	8			ICR	39
IALTDS	9	IBVOLD	32	ICRADU	40
IALTRF	10	IBALT	1217	ICREF [ICRREF]	41
[IATREF]	11				
IALTSA [IATSAM]	12			ICRSRF	42
IANM	445			ICRSPS [ICRSDS]	43
IANM1	13				
IANOP	14			ICSPCP	44
IAN01	15			ICSPSI	45
IASDSP	16			ICSTHT	1200
IASREF [IZC18]	679			ICSPHI	37
IASWTC	18				
IATENG	19				
IATHNS	20				
IATSNG	22				
IAU	23				
IALTNT	1214				
IALFLG	1258				
IALT2	1274				
IABIAS	1350				

C 12

ID		ID		IE	
Name	Cell	Name	Cell	Name	Cell
IDCM13	1204	IDS01	67	IEADIV	81
IDCM32	1205	IDS02	68	IEASFL	82
IDCM33	1206	IDS06	127	IEFAFL	83
IDEADR	46	IDS07	69	IEFDFL	84
IDELCS	47	IDS08	1268	IEFPFL	85
IDELSI	48	IDS12	74	IEFSFL	86
IDEVON	49	IDS13	75	IELVSC	87
IDHOLD	50	IDS14	1277	IENG	88
IDKDLS	54	IDS16	70	IEPDFL	89
IDLACS [IDELSC]	55	IDS18	71	IEPSEA	90
		IDS112	72	IEPSY	91
		IDS113	436	IEPSYL	92
IDLFCS	57	IDS23	47	IEPSYR	93
IDLFLP	58	IDS214	76	IEPSZ	94
IDLFPO	59	IDS35	438	IERNFL	95
IDLRCS	60	IDS43 [IDS44]	437	IEXFLR	96
IDLTIM	61	IDS45	77	IELSFL	441
IDLTQC	62	IDS411	435		
IDLTQO	63	IDS50	1300		
IDMSBS	64	IDS23	73		
IDPSYL	65	IDT12	1283		
IDPSYR	66				
IDT	1244				
IDTX10	1245				
IDFATI	1251				

IF		IG		IH	
Name	Cell	Name	Cell	Name	Cell
IFLATO	97	IGAARM	177	IHDDRF	145
IFD	98	IDACMD	118	IHDTCM	146
IFDVLD	99	ICAMAI	119	IHDVGP	147
IFLAG1	1222	IGAMO	120	IHERRG	148
IFLAG	100	IGAIT	121	IHDGSR [IHGSR]	149
IFLAP1	101	IGBIT	122		
IFLID	102	IGC4HN	123	IHHCMD	150
IFLIP	103	IGDLTS	124	IHREFR	151
IFLPVL	104	IGFRP3	125	IHRNAV	152
IFLPSN	105	IGFRP1	1272	IHCG	1265
IFLARM	106	IGFRPS	126	IGDFLG	1256
IFLRCM	107	IGNDPH	127		
IFPADS [IFPDSP]	108	IGONE	128		
IFPARF	113	IGSARM	130		
IFPAVL	1223	IGSCPD	131		
IFPCMP	110	IGSCUT	132		
IFPFLG	111	IGSDEV	31		
IFPICF [IFPSK]	112	IGSITT	133		
IFPREF	109	IGSREF	134	IJ	
IFURDN	116	IGSVLD	135		
		IGTMGO	136		
		IGTMP	137	IJPTNP	153
		IGTMPO	138		
		IGTMP1	139		
		IGTMP3	140		
		IGT3	141		
		IG199	142		
		IG4DFL	143		
		IG4DCP	144		

IK		IK		IL	
Name	Cell	Name	Cell	Name	Cell
IKAG	154	IKRDCB	181	ILANDS	190
IKALTO	155	IKTHT	182	[ILNDAS]	
IKA1	156	IKTMIL	182	ILATD1	192
IKBRD	157	IDVLGC	184	ILATD2	193
IDCGCR	158	IDVOO	185	ILCARM	194
IKDLSI	159	IDPSI	1257	ILCDEV	195
IKEDO [IKDEO]	160	IKAH1	1259	ILCPFG	196
IKFFO	161	IKGALT	1260	ILCVLD	197
IKFF1	162	IDCGCO	186	ILOCPD	198
IKFLAR	163	K	1299	ILREFL	199
IKFPSA [IKPASA]	164			ILRFAG	200
IKGAMA	165				
IKGCVO	166				
IKGSC2	167				
IKL	168				
IKLO	169				
IKLCY	170				
IKLGCY	171				
IKLGTP	172				
IKLNAV	173				
IKLTY1	174				
IKNDCB	175				
IKPHI	187				
IKPHDB	176				
IKPKPH	177				
IKPRDB	1280				
IKPSDB	178				
IKPDCB	188				
IKQ	179				
IKR	180				

IM		IN		IP	
Name	Cell	Name	Cell	Name	Cell
IMDOF1	201	INAVLD	209	IPALT	1216
		INDEX	210	IPARFL	223
IMFDRP [IMORP]	023	INGZER	211	IPARM	224
IMFDSB	204	INHOLD	212	IPHCLG	225
IMHOLD	206	INMFLG	213	IPHCLX	226
IMNTDN	207	INO	214	IPHCML [IZC6]	667
IMPVLD	208	INOLD1	215	IPHCOM	228
IMDSVO	439	INTOUT	216	IPHCWL	229
IMLSWT	1276	INZMAX	217	IPHCWS [IZC5]	666
MODE	1295	INAV	1281	IPHDCB	231
MO	1296	NOIS1	1285	IPHDOT	232
		NOIS2	1286	IPHI	233
		NOIS3	1287	IPHISN [IPSINC]	254
		NOIS4	1288	IPHOLD	239
		NOISE4	1282	IPIB	240
		INOIS5	1289	IPITFD	241
		N	1298	IPODNK	242
				IPRDEC [IPRGDC]	243
		IO			
		IOLD2	218	IPSDOT	245
		IOLD21	219	IPSDCB	246
		IONBEM	220	IPSIA	247
		IONCRS	221	IPSIC	248
		IOVRFL	222	IPSICA	249
		IONPSC	1250	IPSICF	250
				IPSIDS	251
				IPSIPS	1254
				IPSID3	252
				IPSIE	253
				IPSINC [IPSISN]	254
				IPSRNY	255
				IPSVOR	256

IP		IR		IS	
Name	Cell	Name	Cell	Name	Cell
IPSICR	1207	IRADSC	317	ISASFL	291
IPSICE	1208	IRADES	266	ISBYON	292
IPTARM	257	IRAFLG	267	ISBGSD	293
IPTFD [IPITFD]	258	IRALTC	268	ISBLCD	189
		IRALTF	269	ISEALT	294
IPTFDA	259	IRANGE	270	ISMALK	295
IPTEND	260	IRDELX	271	ISNPSI	296
IPTENG	261	IRDELY	272	ISRTON	297
IPVALD [IPVLID]	262	IRDSEL	273	ISRNVD [ISBNVD]	298
		IREFP	274		
IPSI	1249	IRFNAV	275	ISTDBY	300
IPLVFL	186	IRLARM	276	ISTDMS	301
IPSIPS	1254	IRLENG	277	ISTPTR	302
		IRLERR	278	ISUBAP	303
		IRLFDA	279	ISUBA5	304
		IRMINT	280	ISUMAX	305
		IRNALT	1261	ISUMIN	306
		IRNGFL	281	ISNPHI	1202
		IROLFD	282	ISNTHT	1203
IQ		IRVALD [IRVLID]	283	ISFRCE	1209
				ISPDMS	1255
IQ	264	IRVERS	284		
IQGAIN	265	IRRCMD	658		
		IRSBRA	287		
		IRSVOR	288		
		IRTL	289		
		IRUDSC	290		
		IRWYPT	299		

IT

Name	Cell
ITACCL	307
ITAH-ITASH	308
ITASS	309
ITAUC2	310
ITAU13	311
ITAUIG	312
ITCBER	313
ITCVLD	314
ITCRNG	315
ITCALT	361
ITFLAP	29
ITHAPR [ITHTPR]	316
ITHCOM	318
ITHCMX	319
ITHDEL	320
ITHDOT	321
ITHERR	322
ITHETA	323
ITHOLD	324
ITHRLD [ITHVLD]	329
ITHRNL	326
ITHRTE	327
ITHRTO	328
ITHTCW	518
ITHTSN [ITHSNC]	331
ITIMLF	334
ITKV	335
ITMP	336
ITMPO	337
ITMP1	338
ITMP2	339

IT

Name	Cell
ITMNAJ	340
ITMXAJ	191
ITMSPF	341
ITNAV	342
ITNO	343
ITNOP	344
ITOFRM	345
ITPDCB	346
ITPDC1	347
ITPDC2	348
ITPRIM	349
ITPRTM	350
ITROLL	351
ITVENA	352
ITYAW	353
ITWYPT	443
IT	1296

IU

Name	Cell
IUHOLD	354

IV

Name	Cell
IVAIRC	355
IVCARF	356
IVCERR	357
IVCPFG	358
IVCREF	359
IVGPRM [IVPGRM]	360
IVHOLD	362
IVHOLD1	363
IVK	364
IVMAX	365
IVMAXI	366
IVMAXH	367
IVMNH	368
IVMNH1	369
IVMXH1	370
IVMIN	371
IVMINI	372
IVRFAG	373
IVREFL	374
IVTARF	375
IVTON	376
IVWYPT	378
IVELNT	1215

IW		IX		IY	
Name	Cell	Name	Cell	Name	Cell
IWLCMD	379	IXBRA	410	IYDA	421
IWPC	444	IXDA	411	IYDAP	422
IWPCDS	380	IXDAP	412	IYDDRA	423
IWPC1	381	IXDDRA	413	IYDDRI	424
IWPC11	382	IXDDRI	414	IYERR	425
IWPFLG [IGFRPS]	126	IXNPTH	415	IYRN	426
		IXNROL	416	IYTCAN	427
IWPG	384	IXRN	417	IYVOR1	377
IWPG1	385	IXSBRA	29	IYVALD [IYVLID]	429
IWPL	386	IXTCAN	418		
IWPL1	387	IXVOR1	419	IYWYPT	430
IWPM	388	IXWYPT	420	IYINT	1219
IWPN	389	IXINT	1218	IYDOTN	1220
IWPN01	390	IXCG	1247	IYCG	1248
IWPNP	1253	IXPTIM	1252		
IWPNP1	391				
IWPNI	392				
IWPPVI	393				
IWPV1	394			IZ	
IWPRNG	395				
IWPR1	396				
IWPT1	397			IZDDRA	431
IWPXR	398			IZGTMP	433
IWPXR1	399			IZRN	1213
IWPX1	400			IZRNSV	1212
IWPYR	401			IZDOTN	1221
IWPYR1	402			IZVOR1	432
IWPY1	403			IZWYPT	442
IWPZ1	404			IZCG	1246
IWRD2	405			IZPOS	1275
IWRD29	406			IZ	1297
IWFRCE	1210				

ARRAYS	
Name	First Cell
IANM (15)	450
IBNM (15)	465
ICSKP2 (28)	480
ID (17)	1300
IMD (5,2)	1325
IDZC (18)	510
IDZG (14)	530
IDZN (12)	545
IDLTVC (4)	560
IFLANG (4)	564
IPHICL (2)	234
IPHIRL (2)	236
IKFLAP (2)	568
ISNKP2 (28)	570
ITBNK2 (2)	600
ITWASH (15)	602
IWASH (15)	617
IZN (12)	632
IZG (14)	647
IZC (18)	662
IZGTMP (14)	682
IYC (18)	1150
IY (14) [ZG]	1168
IY (12) [ZN]	1182
IANMI (30)	700
IBNMI (30)	730
IWPXI (30)	760
IWPYI (30)	790
IWPZI (30)	820
IWPRI (30)	850
IWPVI (30)	880
IWPTI (30)	910
IWPXRI (30)	940
IWPYRI (30)	970
IWPGI (30)	1000

ARRAYS (cont'd)

Name	First Cell
IWPLI (30)	1030
IWPCI (30)	1060
IWPVMX (30)	1090
IWPVMN (30)	1120

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